San Francisquito Creek Watershed Conditions Analysis and Sediment Management Plan

2002-2003

GB1399.8 S351 S32003c.1

Historic Conditions
Analysis

SANTA CLARA VALLEY WATER DISTRICT
LIBRARY
[illegible] ALMADEN EXPRESSWAY
SAN JOSE, CALIFORNIA 9511[illegible]

anta Clara Valley
ater District

5750 ALMADEN EXPWY
SAN JOSE, CA 95118-3686
TELEPHONE (408) 265-2600
FACSIMILE (408) 266-0271
www.valleywater.org
AN EQUAL OPPORTUNITY EMPLOYER

October 3, 2003

Mr. Dale Bowyer
San Francisco Bay Region
Regional Water Quality Control Board
1515 Clay Street, Suite 1400
Oakland, CA 94612

Subject: San Francisquito Creek Watershed Historic Conditions Report

Dear Mr. Bowyer,

I am pleased to submit the enclosed *San Francisquito Creek Watershed Historic Conditions Report*. This report is the work product for *Task 1 - Gather Existing Data and Information* of the *San Francisquito Creek Watershed Sediment Assessment Workplan* (revised June 2003) for implementation of the watershed sediment assessment and analysis for San Francisquito Creek. The workplan fulfills the Santa Clara Valley Urban Runoff Pollution Prevention Program (SCVURPPP) Permit Provision 9(f) (*i*) of Order 01-024 of the Regional Water Quality Control Board's (RWQCB) adopted on February 21, 2001, and fulfills the San Mateo Countywide Stormwater Pollution Prevention Program (SM-STOPPP) Permit Provision C. 10 of Order 99-059 of the RWQCB's adopted on July 21,1999.

The report is submitted jointly by the co-permittees of the two Programs (SCVURPPP and SM-STOPPP) in the San Francisquito Creek watershed in order to provide a coordinated and cooperative effort by the two programs; these agencies include the following: County of San Mateo, City of East Palo Alto, City of Menlo Park, City of Portola Valley, City of Woodside, County of Santa Clara, City of Palo Alto, and Santa Clara Valley Water District. In addition, several agencies have also greatly contributed to the implementation of the project, especially the San Francisquito Creek Joint Powers Authority, who is serving as the Prop 13 Grant Administrator and Project Manager, under which this effort is undertaken. Other participating agencies include the United States Geological Survey, Stanford University, the San Francisquito Creek Watershed Council, and CLEAN Southbay. We wish to thank these agencies for their continued participation in this coordinated effort and assistance in developing this report.

If your have any questions concerning this matter, please contact me at (408) 265-2607, extension 2928, or email at RNarsim@valleywater.org .

The mission of the Santa Clara Valley Water District is a healthy, safe and enhanced quality of living in Santa Clara County through watershed stewardship and comprehensive management of water resources in a practical, cost-effective and environmentally sensitive manner.

October 3, 2003

Sincerely,

Roger Narsim
Engineering Unit Manager
Countywide Watershed Programs Unit
Santa Clara Valley Water District

Enclosure (1): Historic Conditions Report, May 2003
Express Delivered on October 3, 2003
cc: Adam Olivieri (EOA), Program Manager, SCVURPPP
Robert M. Davidson, Program Coordinator, SM-STOPPP
SCVURPPP Co-permittees (see attached distribution list)
SM-STOPPP Co-permittees (see attached distribution list)
lcy:lcy
histrpt.100103.SCVWDlet
bcc: B. Goldie, R. Narsim, B. Calhoun, Distribution List

SCVURPPP Co-Permittees

Laura Young
Santa Clara Valley Water District

Phil Bobel
City of Palo Alto

Joe Teresi
City of Palo Alto

Steve Homan
County of Santa Clara

SM-STOPPP Co-Permittees

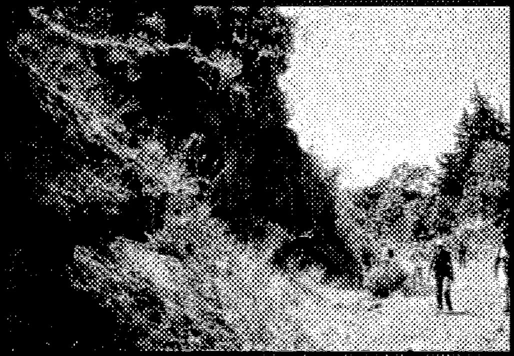
Lisa Ekers
County of San Mateo

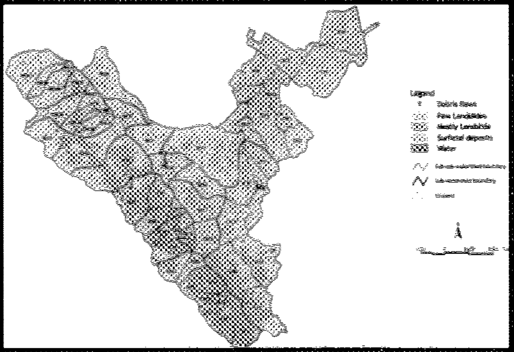
Debra O'Leary
City of East Palo Alto

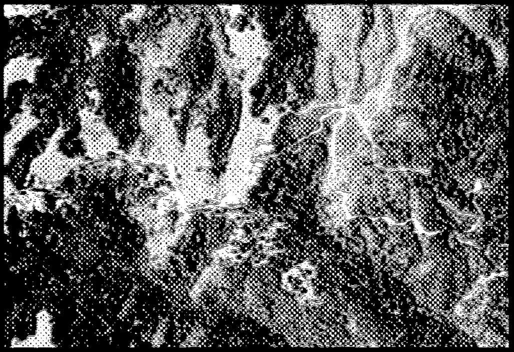
Dianne Dryer
City of Menlo Park

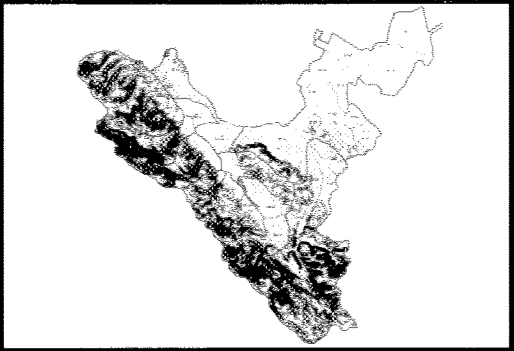
Leslie Lambert
City of Portola Valley

Christina Hovland
City of Woodside









San Francisquito Creek Watershed Historic Conditions Analysis

FINAL REPORT

Prepared for:

San Francisquito Creek
Joint Powers Authority

Prepared by:

nhc northwest hydraulic consultants
Leaders in water resource technology

Jones & Stokes

May 2003

San Francisquito Creek
Watershed Analysis and Sediment Reduction Plan

Task 4.1
Historic Conditions Analysis

Final Report
May 2003

Prepared for:
San Francisquito Creek
Joint Powers Authority

Prepared by:
Northwest Hydraulic Consultants
3950 Industrial Boulevard, Suite 100c
West Sacramento, CA 95691
Contact: Ken Rood
(916) 371-7400

Jones & Stokes Associates
2880 Zanker Road, Suite 210
San Jose, CA 95134

EXECUTIVE SUMMARY

The objective of the Historic Conditions Analysis for San Francisquito Creek Watershed is to describe changes over time in the erosion, transport, and deposition of sediment, partly as preparation for the Task 5 Watershed Sediment Analysis and Task 7 Sediment Reduction Management Plan. The analysis is based on existing databases, reports, maps, or other information, supplemented by additional studies to address important data gaps where these were feasible. Appendix A annotates the reports and databases that specifically address sediment processes in San Francisquito Creek Watershed and summarizes gaps in our knowledge.

Landslides, debris flows, bank erosion, and channel incision in the Santa Cruz Mountains appear to contribute much of the sediment to San Francisquito Creek. These sources are active infrequently, during severe storms and earthquakes. The history of flooding and reports of slope failures suggest that much greater volumes of sediment were contributed at the end of the nineteenth and in the early twentieth century – as a result of several very large storms and the 1906 Earthquake – and over the past thirty years then in the middle years of the twentieth century.

While the historic occurrence of landslides and debris flows is well established, it is not generally known where failures occurred or how many occurred prior to the late 1960s. Since then, government and other reports provide a record of the numbers of large or damaging landslides and debris flows that have occurred in the San Francisquito watershed. The record is incomplete and the volumes from different types of failures, the volumes contributed to streams, and the relative importance of natural and man-made sediment sources have not been determined. To fill the most important data gap, we inventoried all debris flows and slides from recent color air photos, identifying their areas and the role of land use in their initiation.

The steep tributaries in the Santa Cruz Mountains are deeply incised – ongoing erosion of beds, banks and colluvial deposits is an important, but not well-documented source of sediment. However, incision, bank erosion and debris slides seem to be more significant in Corte Madera Creek than in Bear, Los Trancos or the other subwatersheds. Incision and bank erosion are also important sources of sediment along San Francisquito Creek. Here, long-term rates of incision have been estimated from repeated surveys but little is known of the volumes of material eroded from the stream banks during large floods.

Urban development, including clearing of land, impervious areas, and roads are thought to now be the most important human factors that alter streams and sediment supply in the San Francisquito Watershed. Other land uses, such as intensive forest harvesting, agriculture and grazing may have been very significant in the past and may still be locally important. Several reports include overviews of historic land use but there are no studies that describe changes in land use over time or their role in sediment production. To fill this data gap, we measured changes in the road network over time for the subwatersheds, from County and USGS maps. However, land use and vegetation community changes that occurred well before the start of the twentieth century, such as those associated with the intensive logging through the mid-1800s, will never be fully documented.

In the upper watershed, deposition primarily occurs along stream courses in the San Andreas Fault Zone, on the fans constructed by Corte Madera, Sausal and Alambique Creeks at the head of Searsville Lake, and in the lake. Deposited sediments range in size from cobbles to sand, with most of the material being sand. In steep tributaries, bed sediment is deposited locally behind logjams and landslide deposits. Further downstream, sand is deposited along lower San Francisquito Creek (downstream of Pope Chaucer Bridge) and on its delta in San Francisco Bay. The finest sediment fractions are carried past the delta, into San Francisco Bay.

Surveys of the sediment deposits, sediment measurements at stream gages, and sediment transport modeling allow reconstruction of sediment loads from the major sub-watersheds of San Francisquito Creek. Such loads provide an important constraint on the total sediment volume eroded from hillslopes and streams and, combined with field measurements, allow evaluation of the relative contribution of different components of the overall budget over time. Such an analysis will be reported under Task 5, Sediment Analysis.

TABLE OF CONTENTS

LIST OF TABLES IV
LIST OF FIGURES IV
LIST OF APPENDICES IV

1. INTRODUCTION 1

1.1. OBJECTIVES 1
1.2. APPROACH 1
1.3. SOURCES OF INFORMATION 1

2. WATERSHED PHYSIOGRAPHY 2

2.1. BACKGROUND 2
2.2. OVERVIEW 2
2.3. WATERSHED CHARACTERISTICS 2
Geology 3
Physiography 3
Landslide and Debris Flow Susceptibility 4
Stream Network 4
2.4. GAUGING RECORDS (FLOW CHARACTERISTICS) 5
2.5. CONCLUSIONS AND RECOMMENDATIONS 5
Conclusions 5
Recommended Next Steps 5

3. SEDIMENT ANALYSIS OR BUDGETS 6

3.1. BACKGROUND 6
3.2. OVERVIEW OF SEDIMENT SOURCES 6
3.3. SLOPE FAILURES 8
Overview 8
Occurrence in the San Francisco Bay Region 9
Landslide Inventories 9
Debris Flow and Other Inventories 11
Debris Flow and Slide Inventories from Air Photos 12
3.4. OTHER SEDIMENT SOURCES 13
3.5. FAILURE AND EROSION SUSCEPTIBILITY 14
3.6. GRAIN SIZE DISTRIBUTIONS OF SEDIMENT 15
3.7. SEDIMENT STORAGE AND REMOVAL ALONG STREAMS 15
3.8. SEDIMENT TRANSPORT OR SEDIMENT YIELD 17
3.9. CONCLUSIONS AND RECOMMENDATIONS 18
Conclusions 18
Recommended Next Steps 20

4. HISTORIC LAND USE 22

4.1. BACKGROUND 22
4.2. MAPS AND AIR PHOTOGRAPHS 22
4.3. LAND USE 23
Overview 23

Historic Roads and Trails *24*
Impervious Area *24*
Vegetation *25*
4.3. CONCLUSIONS AND RECOMMENDATIONS 26
Conclusions *26*
Next Steps *26*

5. REFERENCES 27

List of Tables

1. Historic Topographic Maps
2. Physical Characteristics of the San Francisquito Creek Subwatersheds
3. Reported Dates of Abundant Landsliding in the San Francisco Bay Region
4. Summary of the Numbers of Damaging Landslides Reported in San Francisquito Creek Watershed.
5. Summary of Debris Flow and Other Slope Failure Inventories in San Francisquito Creek Watershed
6. Summary of Erosion Characteristics of the San Francisquito Subwatersheds
7. Summary of Air Photo Interpreted Debris Slides and Flows in the Subwatersheds
8. Summary of Sediment Excavated near Highway 101
9. Annual Transport Volumes and Denudation Rates in San Francisquito Creek Watershed
10. Summary of Historic Roads in the San Francisquito Creek Subwatersheds
11. Summary of Existing Roads in the San Francisquito Creek Subwatersheds

List of Figures

1. San Francisquito Watershed Boundaries
2. San Francisquito Watershed Slope Map
3. San Francisquito Watershed Geologic Map
4. San Francisquito Watershed Summary Distribution of Slides and Earthflows
5. San Francisquito Watershed Debris Flow Source Areas

List of Appendices

A. Summary of Reports on San Francisquito Creek.
B. Physical Characteristics of the San Francisquito Creek Sub-Subwatersheds
C. Erosion Characteristics of the San Francisquito Creek Sub-Subwatersheds
D. Historic Roads Characteristics of the San Francisquito Creek Sub-Subwatersheds
E. Existing Roads Characteristics of the San Francisquito Creek Sub-Subwatersheds

1. INTRODUCTION

1.1. Objectives

The objective of Task 4.1 is to describe historic conditions in San Francisquito Creek, particularly sediment supply, transport, and deposition as they relate to stream and water quality character, from current knowledge and existing information. We emphasize digital databases that can be incorporated in our GIS analysis. Landslides are a major component of the historic conditions analysis, as described under Task 4.1.d.

1.2. Approach

Our approach is based on a review of existing digital databases, reports, maps, and other information on San Francisquito Creek that are relevant to our objective, an identification of data gaps, followed by additional analyses to address these gaps, where feasible and necessary to achieve project goals. Appendix A summarizes the reports and other information that specifically addresses San Francisquito Creek and provides an analysis of gaps in the record of historic conditions and their significance to later tasks.

The Historic Conditions Analysis is an important precursor to the Task 5 Watershed Sediment Analysis and also to the Task 7 Sediment Reduction Plan. Because these two following tasks rely on different information, we have divided our historic analysis into three parts, as follows:

- Watershed physiography
- Sediment analysis or investigations related to constructing a sediment budget for San Francisquito Creek, emphasizing landslides
- Land use in San Francisquito Creek that provide information relevant to erosion history and sediment reduction plans

1.3. Sources of Information

There is a broad array of maps, GIS data and reports describing physical characteristics, erosion processes, and historic changes in the San Francisquito Creek Watershed. The information reviewed for this task included historic maps and air photos (Table 1), GIS data, reports, maintenance records, and flow and sediment gage records.

The Geological Survey was a key source of information, providing maps, digital orthophotos, GIS layers, and maps and reports describing geology and erosion history in the watershed (Appendix A). The metadata archive at the Palo Alto RWQCP was also an important source of information as were reports and information provided by the JPA and the Technical Advisory Committee. Recent studies by Kittleson *et al* (1996), **nhc** *et al* (2002), and Frey (2001) also provided key information. The following sections describe the sources of information and their data gaps in more detail.

2. WATERSHED PHYSIOGRAPHY

2.1. Background

Physiography, including geology, partly determines the erosion, transport, and deposition of sediment in the San Francisquito Creek watershed. Factors such as elevation, stream and valley slopes, geology, stream networks, and instream channel processes play a key role in determining where sediment is eroded and where it is deposited. As such, understanding and characterizing watershed physiography is an important part of developing a sediment budget and sediment reduction plans.

2.2. Overview

The San Francisquito Creek watershed has an area of about 45 mi^2, most of which lies in the Santa Cruz Mountains southwest of Palo Alto. The Geological Survey's Western Region Geoscience Center has constructed a GIS database that inventories physical and cultural features in the watershed (USGS 2003). Layers in their GIS provide watershed and sub-watershed delineations, faults and fault traces, landslides, digital elevation data, city limits, and other cultural features such as roads and trails. Cultural features are current to 1991-97, the dates of the latest Geological Survey quadrangle maps (Table 1).

We have adopted the watershed boundaries provided by the Geological Survey in their GIS database. They delineate major subwatersheds for the large tributaries to San Francisquito Creek and further sub-divide the tributary subwatersheds into sub-subwatershed. San Francisquito Creek watershed is composed of 10 subwatersheds: San Francisquito, Corte Madera, Los Trancos, Alambique, Martin, Sausal, Westridge, Bear, Bear Gulch, and West Union creeks. Figure 1 shows the various boundaries; Table 2 and Appendix B summarize the characteristics of the subwatersheds and their sub-subwatersheds. We corrected sub-subwatershed boundaries and codes.

Watershed boundaries in the Santa Cruz Mountains and Bay Foothills have remained unchanged over historic time. However, changes to watershed boundaries are thought to have occurred along the lower, urbanized section of San Francisquito Creek where natural drainage has been altered by urban development. The boundaries shown along San Francisquito Creek includes the watersheds of small tributaries to the creek rather than just the area that drains directly to the main creek. The boundaries from Junipero Serra Boulevard to San Francisco Bay are currently being revised by the Santa Clara Valley Water District (SCVWD) to account for changes in storm water drainage. Their work is expected to change some of the sub-subwatershed boundaries. These changes wil be incorporated in the GIS when they are available.

2.3. Watershed Characteristics

The On-line Digital Geologic Map Database (USGS 2003) includes elevation, slope, stream network and geologic maps as well as maps that characterize landslide and debris flow susceptibility and show historic slope failures. Map coverage is by county.

Wentworth *et al* (1985) describe the physical properties of land surface materials in San Mateo County in some detail. Their information has not been incorporated in the GIS.

GEOLOGY

Helley *et al* (1979), Kittleson *et al* (1996), and RHAA *et al* (2000) provide an overview of the geologic history and a general description of the San Francisquito Creek watershed. The San Andreas Fault Zone (SAFZ) is the most prominent feature in the San Francisquito Creek watershed, bisecting the watershed along a northwest-southeast direction. The steep, upper watershed lies southwest of the SAFZ in the northern Santa Cruz Mountains, whereas more gradually sloping areas lie to the northeast (Figure 2). Unstable slopes and active landsliding are predominantly found southwest of the SAFZ (Wentworth *et al* 1997; see also Figure 3).

The upper San Francisquito watershed lies east of the crest of the northern Santa Cruz Mountains and southwest of the SAFZ. The geologic formations in this part of the northern Santa Cruz Mountains consist of Tertiary sedimentary rocks, primarily sandstone, mudstone and shale (Figure 3). Brabb *et al* (2000) provide a description of the various geologic units. The northern Santa Cruz Mountains have had an average uplift rate of about 0.1 to 0.4 mm/year during the Quaternary, significantly less than the southern Santa Cruz Mountains (see Burgmann *et al* 1994; Anderson 1994). Stream incision into bedrock has been an important component of the development of these mountains and the broad alluvial fans and alluvial plain deposited along the shore of San Francisco Bay provide a record of the erosion that has occurred (Anderson 1994).

The Franciscan Complex primarily underlies the Bay foothills northeast of the SAFZ. Large areas of greenstone and graywacke, part of this complex, underlie the southern part of the Los Trancos watershed (Table 2).

Downstream of Searsville Lake, San Francisquito Creek is incised into Pleistocene alluvial deposits and then through an apron of Pleistocene fan deposits downstream of Junipero Serra Boulevard (Helley *et al* 1979). San Francisquito Creek flows in Holocene (recent) alluvium in a valley formed through the older fan deposits. As discussed below, San Francisquito Creek is also incised through these recent deposits. The Holocene deposits are thought to have formed following sea-rise at the end of the last major ice age (Helley *et al* 1979). Kittleson *et al* (1996) report ages of skeletons and organic material of about 4,500 to 5,500 years BP at depths of 16 to 24 feet below the terrace or floodplain surface and, deposition of alluvium must have carried on for some considerable period after these dates before the recent cycle of incision began.

Pleistocene alluvial deposits also fill broad valley in the SAFZ in the upper watershed, such as Portola Valley and Woodside; Los Trancos Creek flows through older Pleistocene alluvial deposits.

PHYSIOGRAPHY

Table 2 summarizes the physical features of each subwatershed, including their area, stream length, basin relief, average stream slope, length of roads, and geology. The physical characteristics of the sub-subwatersheds are provided in Appendix B; Figure 2 provides a slope map of the overall watershed. Figure 2, Table 2 and Appendix B show that steeper, higher subwatersheds are generally located west of the SAFZ whereas those east of the SAFZ are lower in elevation, more gradually sloping, and are more developed, as indicated by the length of roads.

LANDSLIDE AND DEBRIS FLOW SUSCEPTIBILITY

The USGS provides generalized maps of landslide and debris flow susceptibility for San Mateo and Santa Clara Counties, including San Francisquito Creek (Wentworth *et al* 1997; Ellen *et al* 1997), partly derived from previous studies. These maps are discussed further in Section 3.

STREAM NETWORK

The stream network for San Francisquito Creek watershed was adopted from the USGS GIS map (Figure 1). Few studies have examined the historic alignment of streams in the upper San Francisquito Creek watershed. Here, streams are deeply incised over most of their upper courses but deposit sediment along the SAFZ and at the head of Searsville Lake (Frey 2001). Flooding is generally not reported in the upper watershed (Corps of Engineers 1972). Frey (2001) provides descriptions and classification of erosion and deposition for the streams in the Searsville Lake watershed.

nhc and JSA 1999 and **nhc** *et al* 2002 investigated the historic alignment of Corte Madera Creek in the immediate vicinity of Searsville Lake from the late 1800s to present. Aggradation following construction of Searsville Dam resulted in a lowering of valley slope and formation of a large alluvial fan, causing Corte Madera Creek to straighten and occasionally avulse during high flows, causing localized flooding.

Detailed studies of stream morphology in the watershed are limited to San Francisquito Creek downstream of Searsville dam (Royston Hanamoto Alley and Abey (RHAA) *et al* 2000; **nhc** *et al* 2002). These reports examined historic changes in channel alignment by comparing USGS maps and old (1894) surveys. Both studies conclude that San Francisquito Creek has remained in about the same course, but has shifted and eroded its bank in some sections. San Francisquito Creek appears to be most stable upstream of Sand Hill Road where it has incised into local bedrock.

nhc *et al* (2002) examined historic changes in cross-sections along San Francisquito Creek (comparing 1964 to 1998 surveys), from downstream of Junipero Serra Blvd to Highway 101 (see Section 3.8). Some channel cross sections have enlarged through erosion; others are smaller because of revetment placed to control bank erosion. RHAA et al (2000) provide an analysis of present bank stability, indicating that about 40% of the banks are stable and 25 to 30% are severely eroded or unstable. The least stable section of San Francisquito Creek extends downstream from Sand Hill Road.

San Francisquito Creek has incised and its Holocene deposits now form a terrace along most of its course. **nhc** *et al* (2002) compared historical long profiles from 1964, 1968, and 1999 (Junipero Serra Blvd. to Highway 101) and found that the channel invert incised from Junipero Serra Blvd to Chaucer Street over that period whereas it aggraded from Chaucer Street to Highway 101. Incision was typically about one or two feet. Comparison of channel geometry from 1964 with channel depth and width observed by Allardt and Grunsky (1888) indicated that incision had been about 5 ft to 10 ft from 1888 to 1964. Section 3 provides further discussion.

2.4. Gauging Records (Flow Characteristics)

The Geological Survey has one active, long-term stream gauge in the watershed, located on San Francisquito Creek at Stanford University (gage #111645000); gages have operated briefly at other sites in the past. Flow data are available for water years 1932-41 and 1951-present. **nhc** *et al* (2002) reports estimated annual flows for 1899 to 2000, based on correlation with nearby gages. The flood of record on San Francisquito Creek occurred in 1998 with a peak flow of 7,200 cfs. Other notable floods – those exceeding 5,000 cfs – have occurred in 1894, 1895, 1911, 1955 and 1982 (Kittleson *et al* 1996).

The urbanized section of San Francisquito Creek typically runs dry about 6 months each year. Metzger (2002) provided a detailed study of stream flow loss and groundwater recharge on the San Francisquito Creek alluvial fan from 1996 to 1997. Crippen and Waananen (1969) report alterations to flow regimes in small tributaries to San Francisquito Creek that result from urbanization in the early 1960s.

Balance Hydrologics, Inc operates stations on the tributaries to San Francisquito Creek for Stanford University. Measurements began in 1997 on Corte Madera Creek at Westridge Road and in 1995 on Los Trancos Creek at Arastradero Road and they continue to the present (Owens, Chartrand and Hecht 2002).

2.5. Conclusions and Recommendations

CONCLUSIONS

It appears that existing GIS databases and other reports provide much of the background material needed to describe the character of the subwatershed and the sub-subwatersheds of San Francisquito Creek. No additional studies are required at this stage of the project but further analysis of the existing topographic and physiographic data in conjunction with erosion measurements are anticipated as part of the sediment budget task.

RECOMMENDED NEXT STEPS

The next steps consist of incorporating the existing information on watershed physiography with the sediment budget and sediment reduction plan tasks. Steps to incorporate physiography with existing sediment studies are described in the following section.

3. SEDIMENT ANALYSIS OR BUDGETS

3.1. Background

A sediment budget quantitatively describes the volumes of sediment mobilized on hillslopes, the volumes contributed from hillslopes to streams, the transport and storage of this sediment through the stream network, and the yield or volume leaving the watershed. Complete budgets can be very detailed; however, the sediment budget to be constructed for San Francisquito Creek is intended to address specific questions regarding long-term changes in sediment transport (water quality) and stream characteristics, which simplify the analysis. The "Rapid Evaluation" sediment budget that will be completed under Task 5 is expected to address the following questions (see Reid and Dunne 1996):

- Sediment Sources: What are the major or most important types of natural and man-made sources of sediment? What are the approximate amounts of sediment from each source type over time and what portions of the totals have been contributed to streams?
- Sediment Sizes: What are the approximate grain size distributions of sediment from each source, particularly of the portions contributed to streams?
- Sediment Storage: What are the volumes and grain sizes of sediment in storage along the streams? What are the volumes of sediment that are excavated or removed from streams? Where are sediments deposited?
- Sediment Transport or Yield: What are the rates of sediment transport through streams and out of the sub-watersheds?

Appendix A summarizes the existing reports and other documents that address the above questions for San Francisquito Creek and identifies gaps in the available information. Further details are provided in the following section.

3.2. Overview of Sediment Sources

There is no report that evaluates the different sediment sources in San Francisquito Creek. However, Brown and Jackson (1973) do provide an over of erosion processes in South and Central San Francisco Bay. They divided this area into six erosional provinces, based on geology, climate, rainfall, slope, topography, vegetation communities, erodibility, and characteristic sediment erosion and transport processes. San Francisquito Watershed lies mostly in four of their provinces: the Santa Cruz Mountains, Bay Hills, Foothills, and Bay Plains.

In the Santa Cruz Mountains, southwest of the San Andreas Fault zone and covering much of the upper San Francisquito Creek watershed, channel incision leading to undercutting and failure of steep valley slopes was thought to be the main geologic activity. Vegetation cover provides important erosion resistance. Soil and bedrock exposed where vegetation was removed tended to erode rapidly. Kittleson *et al* (1996) provide an overview of sediment sources and erosion processes in the Searsville Lake watershed in the Santa Cruz Mountains. They indicate that slope failures (landslides, road failures and "mudflows"; see below for definitions) are the most important source of sediment. Unpaved roads and trails, bare soils, eroding ditches, cultivated areas, trails and construction and grading are also sources of sediment there. Erosion rates vary with slope and geologic formation. Those formations that are particularly susceptible to erosion have been identified by various authors and are discussed in a later section of this chapter.

Brown and Jackson (1973) indicated that in the Bay Hills, northeast of the SAFZ, soils are often deep, and erosion consists of downslope movement of colluvium and bedrock, by creep, deep-seated landslides and earthflows, although debris flows also occur. Sheet erosion and gullying are common, and can provide large quantities of sediment, when vegetation is removed by development, fire or other activities. The Bay Plain, between the Foothills and San Francisco Bay, is primarily a depositional area. Steep slopes occur along San Francisquito Creek and its tributaries and lateral erosion of unprotected stream banks is thought to be the dominant erosion mechanism.

Erosion and sediment transport is also episodic (Brown and Jackson 1973). Most of the suspended sediment discharge measured on streams in the Bay area occurred during a few storms, particularly those in 1938, 1941, 1952, 1956, 1958, 1967 and 1969. In other years, annual transport is only a small fraction of that which occurs in years when severe storms occur. Inman and Jenkins (1999) document a "dry" period, extending from about 1944 to 1968, along the central and southern California coast when sediment transport is consistently low. They also document an abrupt transition to a "wet" period in 1969, when sediment transport was about five times that in the dry period.

Based on Brown and Jackson's regional study, we anticipate that streams draining different parts of the watershed will be dominated by different sediment sources. In the Santa Cruz Mountains, slope failures (see below for definitions) and bank erosion combined with streambed erosion or incision, are expected to be the most important sediment sources or sediment production processes; surface erosion of roads and slopes may be important in some sub-subwatersheds. We expect that the Santa Cruz Mountains will generate more sediment per unit area than either the Bay Hills, Foothills, or Bay Plains provinces.

In the Bay Hills, surface erosion from roads and disturbed slopes and slope creep are expected to be the most significant erosion processes. Bank erosion may also be important in the Bay Hills and Foothills; this process is thought to be most important sediment source in the Bay Plains along San Francisquito Creek. Hydrologic modifications from suburban development increase peak flows in small tributaries; further aggravating bed and bank erosion there. Surface erosion of developing areas is a significant, but short-lived sediment source (Crippen and Waananen 1969; Knott 1973).

3.3. Slope Failures

OVERVIEW

The Geological Survey provides both geological maps and assessments of geological hazards around San Francisco Bay, primarily from earthquakes and slope failures. Their various studies certainly indicate that slope failures are an important source of hillslope erosion around San Francisco Bay and are significant contributors to storm damage costs, along with flooding.

Slope failures are typically called landslides, defined by the Northern California Landslide Working Group (NCLWG) as “the downslope movement of rock, soil or artificial fills under the influence of gravity”. The actual slope failure processes that are included as landslides have varied over time and from study to study. However, the three most common processes identified by the NCLWG are rockfall, deep-seated landslides, and debris flows (also referred to as “soil slip/debris flows”; see Ellen and Weiczorek 1988). The debris slides or “soil slips” that initiate debris flows are also important sediment sources in San Francisquito Creek (see Frey 2001) but many of these failures are small, obscured by vegetation, and are difficult to identify on air photos or during aerial reconnaissance. Rockfalls do not appear to be a significant slope failure process in San Francisquito Creek and are not discussed further.

As defined, the deep-seated landslides are primarily earthflows and rotational or translational failures in bedrock (NCLWG). Such slope failures usually move slowly and infrequently, often following prolonged rainfall or earthquakes, and leave head scarps and deposits that persist for many years and can be recognized on air photos. Removal or undercutting of toe material by rivers or by human activities (such as road construction or slope re-grading) may re-activate historic landslides or initiate new failures. Pike *et al* (2001) provide a recent summary of the factors that control the distribution of deep-seated landslides around San Francisco Bay. Nilsen *et al* (1976) provide an early evaluation of the factors controlling these failures. Slope, geological formation and the presence of historic landslides deposits are generally recognized as the most important contributing factors.

Debris flows are saturated or supersaturated flows of water and soil. As defined, they include mudflows, debris avalanches and debris torrents (see Swanston and Swanson 1976). Mudflows are primarily composed of fine-grained soils, often move slowly, and may not be very erosive (Varnes 1978). The flows typically originate at a “soil slip” or “debris slide” and then flow downslope (Ellen *et al* 1988). The initiating failure usually occurs on slopes of more than 20°; the flows then travel from a few tens of feet to thousands of feet, often down a steep drainage channel. The largest flows or torrents incorporate soil and organic debris from the bottom and sides of gullies and stream channels greatly increasing their volume. Flows may recur at the same site after soil movement from upslope recharges it.

Debris flows occur episodically and are typically triggered by intense storms that follow seasonal precipitation adequate to saturate the soil profile. Ellen *et al* (1988) note that rainstorms capable of triggering debris flows occur about every five years around San Francisco Bay. Debris flows occurred during at least twelve winters between 1905 and 1978 and during eight winters between 1961 and 1981, indicating a more frequent occurrence in recent years. Cannon and Ellen (1983 & 1985), Wieczorek and Sarmiento (1983), and Wilson and Jayko (1997) describe the precipitation thresholds required to generate abundant debris flows around San Francisco Bay.

OCCURRENCE IN THE SAN FRANCISCO BAY REGION

Both debris flows and landslides are triggered by episodic events, such as severe storms or earthquakes. Consequently, while a few failures may occur throughout the San Francisco Bay region each year, abundant landslides only occur infrequently. Brown (1988) provides a summary of damaging rainstorms that affected the San Francisco Bay region from 1861 to 1982; Smith and Hart (1982) summarize those years when significant landsliding apparently occurred prior to 1982. Since the January 1982 storm, slope failures are thought to have occurred in February 1986 (Keefer *et al* 1987), during the 1997-98 El Nino rainstorms (Godt 1999), and possibly in 1995 (Kittleson *et al* 1996). Table 3 summarizes those years when landslides and debris flows are thought to have occurred around San Francisco Bay and, potentially, in San Francisquito Creek. Brown notes a broad trend of frequent damaging storms from 1879 to 1915, less frequent storms from 1916 to 1937, followed again by frequent storms from 1937 to 1982.

Earthquakes are also an important trigger of deep-seated landslides and debris flows throughout the San Francisco Bay region. Lawson (1908) and Albertson (1908) described the landslides that resulted from the 1906 earthquake; Youd and Hoose (1978) provided an overview of ground failures associated with earthquakes dating back to 1865, although mostly from the 1906 earthquake. They document thousands of "earth slumps" in the Bay region as well as earthflows (possibly mudflows), and earth slides and avalanches (Youd and Hoose 1978; Albertson 1908). In San Francisquito Creek the earth slumps often were observed to originate at or along roads, particularly Bear Creek Road in Woodside and near Page Mill and Alpine Roads. Numerous other undocumented slope failures are likely to have occurred in steep tributaries in the Santa Cruz Mountains of San Francisquito Creek.

Keefer (1998) described the landslides that resulted from the Loma Prieta Earthquake of 1989 (see also Manson et al 1992). No landslides or earthquake features were observed in San Francisquito Creek as a result of the Loma Prieta Earthquake. The nearest features are ten or so miles south of Los Trancos Creek in Santa Clara County.

LANDSLIDE INVENTORIES

While there is general knowledge of the years when landslides likely occurred late in the nineteenth and early in the twentieth century, none of the studies indicate the type of failures, their numbers, or their areal extent in San Francisquito Creek. Brown (1988) notes that detailed study of landslides began in the late 1960s as development spread into the foothills and mountains around San Francisco Bay, resulting in damage or loss of life from landslides that occurred during intense storms. Studies prior to the late 1960's are rare.

Studies in San Mateo County began with an inventory of historic landslides identifiable on air photos, addressing the deep-seated landslides described above (Brabb and Pampeyan 1972). Their map shows large landslide scarps and deposits that may be up to several thousand years old, small deposits, and also active landslides (area greater than 100 ft^2) identified from public sources (Table 4).

The largest landslides in San Francisquito Creek visible on their overview map lie on the eastern slopes of the Santa Cruz Mountains leading to upper Corte Madera and Sausal Creeks and also Los Trancos Creek; few large landslides are shown in the Bear Creek watershed. A digital map is now available as part of the San Francisco Bay Region Landslide Folio that groups San Mateo County into regions of most, many and few landslides (Wentworth *et al* 1997). Figure 4 shows the distribution of these landslide zones in San Francisquito Creek watershed; the highest concentration of landslides occurs in Corte Madera and Los Trancos Creek, lower concentrations occur in Bear and West Union Creeks, and few occur along San Francisquito Creek in the lower watershed. Table 7 summarizes the area of the landslide zones by subwatershed (Appendix C).

The original maps of Brabb and Pampeyan have been revised and updated as part of hazard mapping for Portola Valley (Rodine 1975; Cummings and Spangle & Associates 1975) and Woodside (Dickinson *et al* 1992). These maps provide an indication of the number and area of landslide deposits but do not indicate when such landslides occurred, their total volumes or the volume contributed to streams over time. However, the overall impression is that these large failures have not been very significant contributors of sediment to streams in recent years, although the potential remains for a large failure to contribute huge quantities of sediment to a stream. For instance, a very large failure may have occurred into Los Trancos Creek in 1889-90 (see Table 3).

The Geological Survey has also prepared inventories of damaging landslides around the San Francisco Bay region that occurred during severe storms. These inventories are usually based on aerial reconnaissance, damage reports from the Counties that surround the Bay, and some, limited ground reconnaissance. The numbers of damaging landslides in San Francisquito Creek can be identified from the small-scale maps accompanying the documents; however, the location of initiation points can only be roughly interpreted. The reports describing damaging landslides are (Table 4):

- Taylor and Brabb (1972) – document damaging landslides from the winter of 1968-69
- Taylor, Nilsen and Dean (1975) – document the damaging landslides from the winter of 1972-73
- Creasey (1988) – documents the damaging landslides from the January 3-5th, 1982 storm. Smith and Hart (1982) describe those landslides that resulted in deaths or injury. Weiczorek *et al* (1988) provides details on large landslides that occurred throughout the San Francisco Bay region. No large landslides occurred in San Francisquito Creek.

- Jayko *et al* (1999) – document the damaging landslides that occurred during the 1997-98 El Nino storms. A worksheet describes each landslide, indicating the type of failure, nature of damage, and the volume of sediment involved.

The above studies typically only document those landslides that damage roads, residences or other human structures. They do not provide a complete inventory of the landslides that occurred and do not indicate whether the failures were natural or human-caused, except for the 1997-98 failures. Of the four failures that year, two were along La Honda Road (Highway 84) and one small one occurred in residential landscaping. Human activities likely contributed to these three failures. Table 4 summarizes the number of landslides by subwatershed, confirming the overall severity of the January 1982 storm.

Youd and Hoose (1978) provide maps that show generally where damage was observed on roads and to structures near San Francisquito Creek after the 1906 earthquake. Manson *et al* (1992) and Keefer *et al* (1998) provide maps of landslides resulting from the Loma Prieta earthquake. None of the Loma Prieta landslides occurred in the San Francisquito Creek watershed.

DEBRIS FLOW AND OTHER INVENTORIES

While some debris flows are included in the damaging landslide inventories described above, the only comprehensive inventory of these features followed the January 1982 storm (see Figures 4 and 5 for an inventory for San Francisquito Creek). Broad inventories of debris flows have not been prepared for earlier or subsequent storms; however, Smith (1988) documented debris flows from 1941 to 1982 in a small area in northern San Mateo County from air photos, as did Wentworth (1986) near Montara Mountain for the 1955 and 1982 storms. Weiczorek (1982) documented the occurrence of debris flows and landslides in a small area near La Honda from 1975 through 1981. Smith's analysis indicates that about as many debris flows may have occurred during the 1967 and 1969/70 storms as did in January 1982. Very few debris flows appear to have occurred during the 1937/38 and 1940 storms near Pacifica (Smith 1988).

Weiczorek *et al* (1988) prepared an inventory of the debris flows that occurred in San Mateo County during the January 1982 storms – from aerial reconnaissance, air photos and limited field traverses –and indicated the general factors resulting in their distribution (see discussion in following section). The location of failure initiation points and the approximate lengths of their tracks are provided; however, total volumes or volumes contributed to streams are not reported.

Figures 4 and 5 shows the debris flow initiation points in San Francisquito Creek. Table 5 summarizes the character of the debris flows that occurred in the subwatersheds of San Francisquito Creek; most were relatively small and originated on lower slopes near streams. The average concentrations of debris flows in the subwatersheds of San Francisquito Creek were ranked as "sparse (less than 5 per km^2)" and less than typical concentration throughout San Mateo County (Table 5). No large debris torrents occurred in San Francisquito Creek in January 1982 (Weiczorek *et al* 1988; Smith and Hart 1982).

Frey (2001) documented debris slides, landslides, and debris flows that occurred along lower valley slopes near streams in the Searsville watershed, based on walking each of the channels. The failures were not divided by process but rather into "small" and "large" ones. Most of the failures identified by Frey apparently occurred during the 1997-98 El Nino storms in San Francisquito Creek.

Table 5 summarizes the number and area of small slides Frey observed along the streams and the number of large failures that entered the stream from higher on the slope. All, or nearly all, of the material from these failures directly entered streams; volumes are not reported but might be estimated from the measured areas. These small failures, with an average area of about 300 yd^3, are not thought to be visible from the air or on historic air photos because of obscuring vegetative cover and may not be recorded in debris flow inventories, such as the one that followed the 1982 storm.

DEBRIS FLOW AND SLIDE INVENTORIES FROM AIR PHOTOS

The existing inventories, described above, do not provide a complete record of slope failures in the San Francisquito watershed. To fill this gap, we inventoried the debris slides and flows visible on recent color air photographs (March 2000; nominal scale of 1:22,000). The inventory measured the characteristics of debris slides (soil slips) and debris flows with areas exceeding 400 yd^2 (300 m^2), as follows:

- Sub-subwatershed where the failure occurred
- Type of failure (debris slide or flow)
- Length and width (or height) of failure
- The age of the failure as estimated from revegetation of the scar
- The portion of the failure volume that entered a stream
- Land use near the initiation point, where it was apparent or may have contributed to the failure
- Whether the failure was also enumerated by Frey (2001)

Table 6 summarizes the number and area of failures for each sub-watershed. The failures included in the inventory are typically much larger than the small ones measured by Frey (2001). In most cases the failures she identified could not be seen on the March 2000 air photos; those that could be identified were removed from the air photo inventory so that they were not counted twice.

The air photo inventory certainly indicates that most of the failures occurred in Corte Madera watershed, particularly during recent storms when few failures were observed in the Sausal and Bear subwatersheds. Corte Madera contributes most of the failures in past years also, with reasonably consistent failure areas over the four vegetation classes. About one-thirds of the failure may have originated at roads or have been partly or wholly caused by local drainage modifications. All the other failures occur on slopes that likely have a long history of human modification even though there may be no recent disturbance. Field inspection under Task 5 will estimate volumes and grain sizes for the failures and confirm factors contributing to failure; consequently, the results in Table 6 are only preliminary.

3.4. Other Sediment Sources

Other potential sources of sediment include bank erosion and channel incision, gullying and rilling, surface erosion (sheetwash), and road surface, cut and fill slope, and ditch erosion. Frey (2001) includes a ranking of bank erosion severity in her description and a classification of sediment production from stream reaches in the Searsville Watershed and discussed the apparent channel incision that resulted from the 1997-98 El Nino storms. The volumes eroded from the stream banks are not provided but typically the narrow, incised valley bottoms limit the floodplain area and the total volume that can be eroded from stream banks.

Stream banks have eroded along San Francisquito Creek during large floods, such as occurred in 1955 and 1998, providing sediment to the main stream. The total volumes eroded are not reported and they cannot be easily calculated by comparing surveyed cross sections. Some cross sections show widening as a result of erosion but many other sections have narrowed since 1964, as the result of placing protection on the stream bank slopes after they eroded (**nhc** *et al* 2002).

Kittleson *et al* (1996) report that erosion of road ditches, failures of cut and fill slopes, and sheet wash on gravel-surface roads contribute to sediment loads in the tributaries to San Francisquito Creek. However, we found no studies that document the extent of erosion or the volumes contributed to streams for these sources. In San Francisquito Watershed, large failures have occurred along upper Alpine Road, which is now closed to traffic. Slides and "slipouts" are reported on cutslopes along part of Alpine, Page Mill and Kings Mountain Roads. Ditch erosion may be important along other steep, paved roads. Discussions with maintenance personnel and review of maintenance records during Sediment Analysis (Task 5) will provide a better understanding of the significance of road erosion to total sediment load. Section 4 discusses the historic variation of road and trail lengths in the different subwatersheds.

We found no studies that indicated the extent or importance of surface erosion, gully or rill erosion or other processes that may contribute sediment to San Francisquito Creek. The Geological Survey has sponsored a study of overland flow and sediment transport in San Francisquito Watershed. Chebanov (2001) reports on the initial development of a rainfall-runoff model based on observed microtopography but the model is not, as yet, linked to sediment transport. Knott (1971; also summarized in Brown and Jackson 1973) identified the contribution of different stages of land development to sediment yields in Colma Creek near San Francisco; Crippen and Waananen (1969) provide information on sediment yields from development in three small tributaries in the lower San Francisquito Watershed.

Brown (1973) discussed sedimentation from erosion along roads and exposed slopes in the Zayante and Newell sub-watersheds of the San Lorenzo River. Lehre (1982) provides a detailed sediment budget of a small watershed near Point Reyes Station in Marin County. While not specific to San Francisquito Creek, the above two studies, plus studies of sediment yield from forestry roads, provide useful information on the magnitude of erosion and sediment delivery from processes other than landsliding that may be usefully applied to San Francisquito Creek watershed during Task 5.

3.5. Failure and Erosion Susceptibility

Wieczorek *et al* (1988) provided an assessment of the factors that controlled the initiation of debris flows in San Mateo County based on the distribution observed following the January 1982 storms. Debris flows typically originated as soil slips or slides and then flowed downslope or into steep drainage channels. Typically, the greatest concentrations occur in areas of the most intense rainfall; initial failures occur on slopes greater than 20°; often in swales or concavities; and the number of failures increased with slope. Greater numbers are also apparent on grasslands when compared to forest. Bedrock geology is particularly important and Wieczorek *et al* (1988) indicate those formations or units with low, medium and high incidence of debris flows based on the calculated abundance. Some members of Tertiary sedimentary formations (Purisma, San Lorenzo and Lambert) show medium or high debris flow incidence; others do not.

Both Frey (2001) and Kittleson *et al* (1996) evaluated the susceptibility of different geologic formations in the Searsville Lake Watershed to erosion. Based on their field observations and analysis of erosion activity and severity, they identified the Purisma, San Lorenzo and Lambert formations as significant contributors. They also identified the Santa Clara formation as erodible, although it shows low debris flow incidence.

Mark (1992) provided an initial map of debris flow probability for San Mateo County. Ellen *et al* (1997) later provided a digital map of debris flow source areas, based on slope and slope curvature calculated from USGS quadrangle maps. Figure 5 shows the calculated debris flow source areas and the 1982 debris flow initiation sites for San Francisquito Creek.

Brabb *et al* (1972) ranked the susceptibility of geologic units in San Mateo County to deep-seated landsliding. Their analysis and the one for debris flows (see above) show different formations as most susceptible. Pike *et al* (2001) provides a recent analysis of landslide susceptibility for Oakland that examines the occurrence of historic and recent deep-seated landslides based on geologic formation, slope, and the presence of past landslide deposits. Wentworth *et al* (1997) provide a summary of the areas affected by landslides and earthflows in San Mateo County. Wentworth's classification for San Francisquito Creek is shown in Figure 4.

Table 7 summarizes some of the characteristics of the different subwatersheds that affect erosion, based on the above studies. It includes average slopes, ranking of stream erosion from Frey (2001) for the Searsville Lake subwatersheds, numbers of landslides, debris flows and the portion of the watershed with erodible geology and erodible slopes. Appendix C provides this information for the individual sub-subwatersheds. Analysis at the sub-subwatershed level during Sediment Analysis (Task 5) is expected to provide the best indication of the factors that are critical to erosion in the San Francisquito Creek Watershed.

3.6. Grain Size Distributions of Sediment

Ellen *et al* (1988) provide an engineering analysis of 50 soil samples from sites around San Francisco Bay where debris flows occurred. Gravel contents are low in most samples and clay contents are usually more than 8% and less than 25% for fast moving failures. The content of clay in the samples seems to vary with the underlying geologic unit. No specific studies of the grain sizes contributed by deep-seated landslides or by other processes were found. However, the grain sizes contributed by these processes can be roughly assessed from the characteristics of the soils and the geological formations where they originate (Kittleson *et al* 1996; Frey 2001). Many of the most erosive formations are poorly indurated and seem to provide sand and finer sediment as their main erosion products. The sandy deposits on the fan of Corte Madera Creek at Searsville Lake indicate the nature of the bulk of the sediment supplied by erosion and transported through this watershed.

Wentworth *et al* (1985) characterized the physical properties of land surface materials in San Mateo County, including expansivity of material, cut-slope stability, permeability, excavatability, character of material as fill, texture of surficial mantle, physical properties of bedrock, and geologic unit. These data are useful in describing relative erosivity and grain size distribution of surface material eroded from the watershed.

Detailed measurements of the size of current bed material are available for San Francisquito Creek from Searsville Lake to Highway 101 (see RHAA *et al* 2000; **nhc** *et al* 2002), showing a decline in size from cobbles and boulders near Searsville Dam to sand near Highway 101. The Department of Fish and Game (1981) provides visual observations of bed material and channel form along upper San Francisquito Creek from the early 1980s.

Much less is known of the streambed material in the tributaries. **nhc** and JSA (1999) and **nhc** *et al* (2002) describe bed material on the fan of Corte Madera Creek at the head of Searsville Lake. Coyote Creek Riparian Station (1998; 1994) provides substrate pebble counts and profile surveys near their stations on San Francisquito, Los Trancos, West Union, Bear and Corte Madera Creeks (see also Buchan and Hayden 2000). DFG (1974, 1976, 1985) provide visual observations of bed material on Bear, Corte Madera and Los Trancos Creeks as part of fisheries reconnaissance surveys. Frey (2001) provides some miscellaneous observations on bed material in the Searsville watershed. Many of the steep upper reaches were observed to have scoured to bedrock following the 1997-98 El Nino storms.

3.7. Sediment Storage and Removal along Streams

Frey (2001) ranked sediment storage along stream reaches in the Searsville watershed based on observations following the 1997-98 El Nino storms. Deposition primarily occurs in the lower-gradient reaches of these streams where they flow along the San Andreas Fault Zone and at the head of Searsville Lake, although some sediment was stored in steeper reaches behind logjams and debris slide deposits. Nolan (1988; see also Nolan and Marron 1985) describes the response of channel in the Santa Cruz Mountains to sediment production and landsliding during the January 1982 storm. They note a characteristic pattern of moderate scour in steep, upper reaches with moderate deposition along middle and lower reaches. Material aggraded along the channel was later removed by storms that occurred over the next few months.

Smith and Harden (2001) provide a description of the channels in the Bear Creek watershed as part of an evaluation of barriers to adult steelhead passage. They note storage of coarse sediment behind dams, weirs and some logjams and deposition of (seasonal) fine sediment in pools along low-gradient reaches with an overall clean substrate. Of particular interest, they identify an 11-foot high knickpoint on upper West Union Creek, just past the Huddart Park boundary. They also describe the extent of bank protection and bank stability in the reaches they visited.

Kittleson et al (1996), **nhc** and JSA (1999) and **nhc** *et al* (2002) describe historic channel changes and aggradation along lower Corte Madera Creek resulting from deposition upstream of the head of Searsville Lake. **nhc** *et al* (2002) provide estimates of the volume of recent sediment (1995-2000) deposited on the fan formed there. **nhc** *et al* (2002) also summarize the historic deposition in Searsville Lake, based on earlier surveys. These are discussed further in Section 3.7.

nhc *et al* (2002) describe changes along San Francisquito Creek by comparing 1964 and 1998 surveys and determining the extent of incision and channel enlargement over that period. Two distinct zones of channel behavior were observed. From Pope-Chaucer Bridge to Sand Hill Road, the bed incised; downstream of Pope-Chaucer, the channel aggraded. Incision calculated from comparing the cross sections amounted to about 130,000 tons between El Camino Real and Pope-Chaucer Bridges; aggradation amounted to about 430,000 tons over the same period.

Comparison of the inverts of the two surveys shows relatively slow incision from 1964 to 1998 upstream of Pope-Chaucer Bridge, amounting to about two feet, or a rate of about 0.06 feet/year. Comparison of the 1964 surveys to the channel depth and width observed by Allardt and Grunsky in 1888 shows incision of about 5 to 10 feet downstream of Sand Hill Road, or a rate of about 0.06 to 0.12 feet/year. (Bedrock control in the channel bed upstream of Sand Hill Road apparently prevented incision there.) Differences in incision rates and the overall flattening of the slope may be related to reduced sediment supply, exposure of resistant material in the streambed, deposition along lower reaches associated with growth of the San Francisquito Creek delta or movement of the mouth north after 1930, or altered peak flow regimes.

Bed material has been historically removed from San Francisquito Creek to maintain the capacity of the Highway 101 Bridge. Deposition typically occurs on the left (north) bank and during large floods a few to five or six feet accumulate. Excavation usually extends upstream and downstream from the bridge for a few hundred feet or so: the excavated material consists of sand and pebbles. Table 8 summarizes the quantities that have been removed since 1984, as provided by the Santa Clara Valley Water District (SCVWD). Excavation volumes prior to 1984 are not reported.

Table 8: Summary of Reported Excavation at Highway 101

Year	*Comment*	*Reported Volume (yd^3)*
1984	Upstream and downstream of 101	3,290
1993	Downstream of bridge	1,260
1998	Emergency work	3,080
1997	Downstream of bridge	4,630
2000	Downstream of bridge	4,882
Total		17,142

The above table shows greater removals in recent years; however the removals remain small when compared to the deposition through this reach, as described above.

Phillips (2000) summarizes deposition on the delta at the mouth of San Francisquito Creek in San Francisco Bay, based on detailed coring of the delta. His results show five sand layers that are spread extensively over the delta, which he associated with the five largest floods since 1930 when the mouth of the creek was moved north. The individual layers are not dated and cannot be readily assigned to specific storms; however, the uppermost layer is certainly a result of the 1997-98 storms.

The volumes of sand deposited during each event can be roughly estimated from the mapped area and the cores. For instance, it appears that the sand layer deposited on the delta during the 1997-98 El Nino storms averaged about 6 inches thick; based on the observed distribution of the flood deposits as much as 30,000 to 40,000 yd^3 of sand may have been deposited. The volumes deposited during earlier floods are not as easy to estimate and their extent, as indicated by the thickness and continuity of the sand deposits in the cores, is not as well known. However, the earlier deposits seem to be smaller than that from 1997-98.

3.8. Sediment Transport or Sediment Yield

Certainly, the longest record of sediment yield is from deposition in Searsville Lake by Corte Madera, Sausal, and Alambique Creeks. Repeated reservoir surveys provide average sediment deposition from 1892 to 1913; 1913 to 1929; 1929 to 1946; 1946 to 1995; and from 1995 to 2000 (**nhc** *et al* 2002). Deposition in the reservoir underestimates total sediment transport from the Searsville watershed. This occurs for two reasons. First, the finest grain sizes are carried over Searsville Dam to San Francisquito Creek so they are not included in the total, and second, coarse sediment that has accumulated on the fans of Corte Madera, Sausal and Martin Creeks upstream of the reservoir has not been surveyed, except between 1995 and 2000 (**nhc** *et al* 2002). The sediment that passes over the dam amounts to about 10% of the incoming load; adjustments for deposition on fans at the head of the lake can only be prepared for the most recent period. Table 9 summarizes deposition volumes and calculated denudation rates in Corte Madera and Searsville Lake watersheds. Long-term rates are reasonably consistent with the long-term uplift rate in the northern Santa Cruz Mountains.

The Geological Survey operated a gauging station on San Francisquito Creek at the Stanford Golf Course from 1931 to 1941 and then 1951 to present (Section 2.4). Brown and Jackson (1973) report on a suspended sediment sampling program at this gauge for the period from 1962-1969. Annual loads at the station can be assumed to be nearly entirely from Los Trancos and Bear Creeks and they provide an indication of historic suspended (fine) loads from these two subwatersheds. Balance staff also collected a few measurements at this gauge during the 1998 water year to compare to the previous sediment-rating curve (**nhc** *et al* 2002). Table 9 summarizes annual suspended loads reported by Brown and Jackson and calculated denudation rates in Bear and Los Trancos watersheds. Denudation rates on Los Trancos and Bear watersheds are highly variable from year to year but average much lower than observed in Corte Madera Creek watershed. The HEC-6 model (**nhc** *et al* 2002) will be used to estimate long-term sediment supply from Los Trancos and Bear Creeks as part of the Sediment Analysis (Task 5).

Balance Hydrologics, Inc has undertaken flow and suspended and bedload sediment gauging in the San Francisquito watershed for Stanford University in recent years. Their sediment measurement program includes both suspended and bedload sediments. Records began in 1997 on Corte Madera and in 1995 on Los Trancos Creek (Owens *et al* 2002). They also measured sediment discharge on Searsville Dam, Bear, Sausal, Dennis Martin, Westridge and Alambique Creeks during the 1998 water year (**nhc** *et al* 2002). Balance has prepared annual reports on their gauging programs in Corte Madera and Los Trancos. We have not reviewed these in detail. Instead, we relied on the summary provided in **nhc** *et al* (2002) that describes total loads over the period of record and provides sediment-rating curves for Bear and Los Trancos Creeks and estimated rating curves for the streams flowing to Searsville Lake.

The HEC-6 model of San Francisquito Creek will be operated to estimate longer-term suspended and bed load transport from Los Trancos and Bear Creeks (**nhc** *et al* 2002). These volumes can then be combined with the calculated incision and deposition along San Francisquito Creek, excavation volumes, and the material deposited on the delta fan discussed above, allowing a reasonable estimate of bank erosion volumes along San Francisquito Creek and completing a coarse sediment balance for the lower river for the period from 1964 to 1998.

3.9. Conclusions and Recommendations

CONCLUSIONS

Landslides, debris flows, bank erosion, and channel incision in the Santa Cruz Mountains appear to contribute much of the sediment to San Francisquito Creek. These sources are active infrequently, during severe storms and earthquakes. The history of flooding and reports of slope failures around San Francisco Bay and in San Francisquito Watershed suggest that much greater volumes of sediment were contributed at the end of the nineteenth and in the early twentieth century – as a result of several very large storms and the 1906 Earthquake – and over the past thirty years then in the middle of the twentieth century. Development seems to an important contributor to the slope failures. Surface erosion along roads and on exposed soils is also an important sediment contributor in the Santa Cruz Mountains. Surface erosion, soil creep, and bank erosion along San

Francisquito Creek and its tributaries are the most important sources in the lower watershed, through the Bay Hills and Bay Plain. Much less is known of the history of surface erosion in the watershed but development is thought to have increased its contribution at different times through logging, road construction and clearing for construction.

While the historic occurrence of landslides and debris flows is well established, it is not generally known where failures occurred or how many occurred prior to the late 1960s. Since then, government and other reports provide a record of large or damaging landslides and debris flows that have occurred in the San Francisquito watershed. Documentation consists mostly of numbers of landslides or debris flows. The record is incomplete and the volumes from different types of failures, the volumes contributed to streams, and the relative importance of natural and man-made sediment sources have not been determined. The best records are from the January 1982 storm – which seems to have caused a large number of landslides in San Francisquito Creek – and from the 1997-98 El Nino storms. Air photo interpretation and field inspections are required to estimate volumes of sediment contributed during these storms by landslides, debris flows and channel erosion and to estimate contributions from other source types in San Francisquito Watershed.

The steep upper tributaries in the San Francisquito Watershed are deeply incised – ongoing erosion of beds, banks and colluvial deposits is an important, but not well-documented source of sediment, except in the Searsville watershed after the 1997-98 El Nino storms. Incision, bank erosion and debris slides along channel margins seem to be far more significant in Corte Madera Creek than in Bear Creek or the other watersheds. Incision and bank erosion have also been on-going sources of sediment along San Francisquito Creek. Here, long-term rates of incision have been estimated from repeated surveys but little is known of the volumes of material eroded from the stream banks during large floods.

In the upper watershed, deposition primarily occurs along stream courses in the San Andreas Fault Zone, on the fans constructed by Corte Madera, Sausal and Alambique Creeks at the head of Searsville Lake, and in the lake. Deposited sediments range in size from cobbles to sand, with most of the material being sand. In steep reaches, bed sediment is deposited locally behind logjams and landslide deposits. Further downstream, sand is deposited along lower San Francisquito Creek (downstream of Pope Chaucer Bridge) and on its delta in San Francisco Bay. The finest sediment fractions are carried past the delta, into San Francisco Bay.

Surveys of the sediment deposits, combined with sediment measurements at stream gages, allow reconstruction of sediment loads from the major sub-watersheds of San Francisquito Creek. Annual loads have been reconstructed for some tributaries; further HEC-6 modeling will allow reconstruction of loads for Bear and Los Trancos subwatersheds. Such loads provide an important constraint on the total sediment volume eroded from hillslopes and streams and, combined with field measurements, help evaluate the relative contribution of different components of the overall budget.

RECOMMENDED NEXT STEPS

The major focus of the Sediment Analysis task (Task 5) will be on quantifying volumes from different sources based on existing studies and fieldwork, extending these studies back historically, and on identifying human or man-made contributions to erosion.

Volumes from Slope Failures

Based on field studies, estimate typical or average depths of failure and sizes of material and calculate average volumes for the different types of failures. Assign volume contributions to different storms or periods based on field inspections, further air photo analysis and climate records or other studies.

Sediment Balance Studies

Complete a detailed sediment balance for the period from 1995 to 2000 for the tributaries to Searsville Lake. Review Frey's (2001) data base on landslides along streams and bank erosion and assign sediment source volumes to the different classes of sediment production severity. Estimate the sediment production from other sources, such as surface erosion, road erosion, and soil creep from other studies, and add contributions from large landslides or debris flows measured on air photos. Calibrate the sediment source contribution to streams by comparing total and average production to records of sediment accumulation in Searsville Lake, after adjustment for deposition.

A similar study will be completed for Bear and Los Trancos Watersheds as described below, based on sediment yield estimated from the HEC-6 model of San Francisquito Creek. These two studies of the tributaries will then be combined to construct a sediment balance for San Francisquito Creek that compares sediment contributions from contributed by Bear and Los Trancos Creeks with observed deposition, sediment removals and bank erosion along the main creek. Such sediment balance studies will allow estimation of quantities contributed by sources that have not been traditionally measured or are very difficult to measure.

Extend the Observations to Los Trancos and Bear Creeks

The key watershed components that control current and historical sediment production have not changed significantly over the years, although the numbers of failures that occur are greatly influenced by the intensity and duration of rainfall. These components include basin geology, previous sites of failures or areas susceptible to failure, watershed slope, and stream slope. Once the initial studies are completed to document erosion and sediment transport in the Searsville Lake sub-subwatersheds, we will attempt to relate these rates to basin geology, landslides or debris flow susceptibility, and basin and stream slope. A qualitative or semi-quantitative ranking will be developed to identify sub-subwatersheds which have physical characteristics that make them prone toward high sediment production, such as certain lithologies, a specific range of slopes, number and scale of past slope failures, or the proximity of streams to landslide deposits. Such information will be input into the GIS and queried to identify, for example, areas where certain high sediment producing geologies coincide with slopes in a particular range.

Such relationships between sediment production, geologic formation, slope, and historic landslides, combined with a reconnaissance flight will allow a preliminary calculation of sediment production for stream reaches in Los Trancos and Bear Creeks to complement the estimated landslides and debris flow volumes. As part of Task 5, field studies to confirm or adjust the preliminary calculations will be completed.

Contributions from Other Sediment Sources

The other significant sources of sediment are expected to be surface erosion, both on natural and disturbed slopes and on landslide scars, surface and ditch erosion along roads, and gullying and rilling. Volumes of sediment from these sources are not documented and we will identify to quantify erosion by these processes as follows:

- Aerial reconnaissance and review of infrared air photos to identify areas of exposed or bare soils, where overland flow and sheetwash erosion and rilling or gullying of slopes may occur. Typical rates of erosion from other studies would then be applied to these areas to estimate the total erosion and the contribution to streams.
- Discussions with maintenance staff of San Mateo and Santa Clara Counties and field inspection of roads and trails to identify ditch erosion and gravel-surfaced roads that contribute sediment from surface erosion. Once the features of the different roads are determined by field inspection, apply various models to estimate annual sediment production from these sources.

The recent sediment contribution from these sources will be evaluated from other studies in the region that have considered appropriate rates for these processes. We anticipate that it may be practical to estimate the historic variation in the contributions from these sediment sources using the land use analysis described in the following Section.

Channel Incision Studies

Channel incision along tributaries to San Francisquito Creek is thought to be an important sediment source. However, it has not been documented. We will compare historic bridge design drawings or bridge surveys to the current channel to develop a better understanding of channel incision throughout the San Francisquito Creek Watershed

4. HISTORIC LAND USE

4.1. Background

The historic analysis of land use is intended to provide information on human modifications or developments in the San Francisquito Watershed that have either directly affected streams and sediment supply or have indirectly affected them by altering sediment supply, hydrology, vegetation communities, or topography. Urban development, particularly roads, clearing for development, construction of impervious areas, and modifications to drainage (including levees) is now thought to have the greatest effect on hydrology and sediment supply, and thus on streams. However, agriculture, grazing, forest harvesting and other land uses may have been important historically and may continue to affect streams and sediment supply.

This section provides an overview of historic land use, with details on historic roads. Further information on historic vegetation and land use is provided in the Existing Conditions Report, prepared as part of Task 4.2, rather than here in the Historic Conditions Report, as they seem best presented with an analysis of aquatic habitat and other similar information.

4.2. Maps and Air Photographs

Historic maps of the San Francisquito Creek basin from 1899 to 1997 were collected from the Geological Survey (Table 1). Digital versions of these maps were also obtained for use in the GIS. Although other historic maps exist, they were not pursued as they lack the combination of detail and wide area of coverage provided by maps from the Geological Survey. San Mateo County provided maps of their County, showing roads and other features, from 1868, 1909, 1927, 1960 and 1973.

Historic air photos were investigated using the air photo library at the University of California at Santa Cruz and the Air Photo Search and Retrieval System (APSRS) of the Geological Survey. Both sources offer a large availability of air photos for the San Francisquito watershed, dating from the early 1940s to present. Watershed coverage varies from one air photo set to another. Years with full or almost full coverage include 1960, 1980, and 1982. These photos are of limited use in a GIS because they are not rectified and are not available in digital form. However, air photos from 1948 and 1993 were available for the entire watershed as Digital Orthophoto Quadrangles (DOQs) and, unlike conventional contact prints, are available in digital form, rectified, and easily imported into a GIS database. The 1899 USGS map and the 1948 and 1993 DOQs were overlain with the subwatershed and sub-subwatershed boundaries. These maps are the main source of information for the historic land use changes discussed in detail in the Existing Conditions Report.

4.3. Land Use

OVERVIEW

Considerable information is available for recent and current land use within the study area, but we were not able to locate any maps, databases, reports or other documents that analyzed changes in land use throughout the watershed over time. Some general descriptions of land use changes from the late eighteenth and early nineteenth century are available. The Santa Clara Basin Watershed Management Initiative (SCBWMI 2000) provides an overview of urban development in the Santa Clara Basin, including San Francisquito Creek. They note a broad trend of agricultural development on valley bottoms starting in the 1850s, followed by intensive agriculture, with urban growth and industrial development replacing agriculture following World War II. Most Highways were built by the mid-1940s with freeway construction in the 1950s and 1960s. Brown (1966) and Stanger (1967) provide a history of early logging on the San Francisco Peninsula around San Francisquito Creek. Locally, Portola Valley provides a timeline of events in their community, emphasizing dates of when developments began and populations through time.

SCBWMI (2000) provides an overview of existing land use along the west side of the Santa Clara Basin. They note a distinct transition occurs at around 600 to 800 feet elevation; typically forest and rangeland lie above these elevations, urban areas lie below. Forest typically dominates rangeland on the western basin slopes, in the Santa Cruz Mountains. The upper watershed of San Francisquito Creek is mostly undeveloped, similar to other creeks on the west side of the Santa Clara Basin. It differs from these watersheds in that it has a greater portion of moderate density residential development, heterogeneity of land use, and has large areas of forest and rangeland, including some agriculture, at lower elevations. SCBWMI (2000) provides an existing (1995) land use breakdown for the entire watershed but does not separate land uses for the subwatersheds or sub-subwatersheds.

A variety of sources were contacted to obtain digital databases for historic and existing land uses within the San Francisquito watershed. The Santa Clara and San Mateo Counties general plan land use designation maps were consulted to identify mapped land uses within the project area. Although present land uses have been designated and defined through these planning documents, the polygons that define each area are very broad, and do not provide specific land use information for the watershed. Similarly, the California Department of Water Resources has mapped general land use throughout much of California. Their mapping was based on aerial photo review, their designations are broad in nature, and they do not necessarily represent the existing land uses found today throughout the watershed.

The most complete source of digital land use data for existing conditions is from the Association of Bay Area Governments (ABAG). They provide maps for the San Francisco Bay region and their classification system provides detailed definitions for each land use polygon that has been identified. The USGS previously prepared a land use map for San Mateo County from an earlier version of the ABAG database (Napier *et al* 1992).

We are now obtaining the ABAG digital database for the San Francisquito Watershed as the best descriptor of existing land use. We will compare this coverage to the historic land use visible on USGS maps and DOQ to measure changes that have occurred over time throughout the watershed. To the extent possible, the land uses identified through historic maps and air photographs will be correlated with the land use designations for existing conditions. This analysis will be reported in the Existing Conditions Report under Task 4.2.

HISTORIC ROADS AND TRAILS

We did not find a report that inventories the historic roadways and trails in the San Francisquito Watershed. Therefore, the best source for historic roadways and trails, and the extent to which these have changed over time, are the historic air photos and maps described in the "Maps and Air Photos" section above. Table 10 summarizes the measured lengths of historic paved and unpaved roads and trails and the numbers of stream crossings for each subwatershed; Appendix D provides the same information for the sub-subwatersheds. The table shows the overall growth of the road network and that the length of unpaved roads and trails in 1968 is only a little less than at the end of the nineteenth century, at around 100 miles. Note that the earliest period for the roads and trails is a combination of the 1868 San Mateo County Map and the 1899 USGS map. These were combined in order to obtain complete coverage of the watershed. The road analysis does not necessary describe all the roads and trails developed for forest harvesting in the Santa Cruz Mountains. Brown (1966) and Stander (1967) provide some information on these earlier roads.

The existing road network was obtained from USGS maps, based on the most recent editions (Table 1) and incorporated into the GIS of the watershed. Table 11 provides a summary of the length of roads and trails by subwatershed, the length of road crossing different slope classes, and the length on erosive geologic formations. Appendix E provides a similar analysis for the sub-subwatersheds.

The Mid-Peninsula Regional Open Space District (MROSD) owns and manages several open space areas within the watershed. These open space areas contain a variety of logging roads, and biking and hiking trails that have been mapped by MROSD. To supplement their information, local trail councils and the general plans for Santa Clara and San Mateo Counties are being examined to identify the trails outside of the MPROSD lands, but within the study area, that are not shown on existing maps. The inventory of these trails will be described in detail in the Existing Conditions Report.

IMPERVIOUS AREA

Only one study of impervious area in the San Francisquito Creek watershed was identified during the literature search. EOA, Inc. (1998) estimated impervious area cover for the whole watershed based on existing land uses (1995) and estimates of impervious cover for about 40 different land use categories. Total impervious cover for the basin was estimated to be 22%. Although useful for comparison with other nearby watersheds, and helpful as part of an index of watershed health, their study did not provide estimates of impervious cover for the subwatersheds or sub-subwatersheds and does not calculate the historic changes in impervious cover required to evaluate changes in streams and sediment production in the watershed.

VEGETATION

Considerable information is available for existing vegetation communities within the study area, but we were not able to locate any maps, databases, reports or other documents that analyzed changes in vegetation communities throughout the watershed over time. **nhc** *et al* (2002) provides the most recent overview of historic vegetation in San Francisquito Watershed and the changes that have occurred in these communities; some earlier reports also provide an overview. While there is a general understanding of the changes that have occurred in vegetation communities over time, major changes, particularly those resulting from agriculture, grazing and intensive logging in the mid-to late eighteenth century, are not well documented. Brown (1966) and Stanger (1967) provide a history of early logging on the San Francisco Peninsula but do not provide details for San Francisquito Creek.

Existing vegetation communities within the study area have been mapped using the Wetland Habitat Relationship (California Department of Forestry and Fire Protection 1988) inventory, supplemented by the National Wetland Inventories Classification of Wetlands and Deepwater Habitats of the United States (NWI) (U.S. Department of the Interior, U.S. Fish and Wildlife Service 1992) and the California Natural Diversity Database (California Department of Fish and Game 2003). The WHR system provides a broad vegetation classification system to categorize the major vegetation communities throughout California, and provides a description for each habitat classification. The NWI and CNDDB databases include polygon mapping of wetland and sensitive vegetation communities, respectively. Within the study area, the vegetation communities that have been identified through the WHR classification system have been further defined through the addition of supplemental information from the NWI and CNDDB databases. This information includes mapping of sensitive vegetative communities, including wetlands, riparian corridors, and oak woodlands. Existing vegetation communities and areas of bare soil can also be interpreted from supervised classification of the 2002 color infrared photographs of the San Francisquito Watershed. This is also discussed further in the Existing Conditions Analysis.

In order to measure changes in vegetation communities over time, historic air photographs, as described above under the "Maps and Air Photographs", will be used to classify or categorize vegetation. To the extent practical, the vegetation communities identified on historic maps and air photographs will be correlated with the designations for existing conditions. This analysis will be reported in the Existing Conditions Report under Task 4.2.

4.3. Conclusions and Recommendations

CONCLUSIONS

Urban development, including clearing of land, impervious areas, and roads are thought to now be the most important human factors that alter streams and sediment supply in the San Francisquito Watershed (see also Section 3). Other land uses, such as intensive forest harvesting, agriculture and grazing may have been very significant in the past and may still be locally important. A number of overviews of historic land use have been prepared but we found no studies that describe the historic changes in these land use characteristics or their role in sediment production in detail.

As part of the historic analysis, we measured changes in the road network over time for each subwatershed from County and USGS maps, as roads are thought to be an important component of human-caused erosion. The earliest roads are shown on an 1868 San Mateo County map; however, this early map may not include all of the roads built for forest harvesting in the mid-1800s. Trails may also not be adequately represented. Further analysis of the trail network will be included in the Existing Conditions Report.

The main sources of information for historic land use and vegetation communities are historic topographic maps, which date to 1899, and historic air photos, from the early 1940s. Analysis of land use and vegetation communities from these sources will be reported as part of Existing Condition Analysis and will be integrated into the Sediment Analysis (Task 5). These changes are thought to be important to analysis of human-caused erosion. Historical land use and vegetation community changes that occurred before start of the twentieth century, such as the intensive logging that occurred through the mid-1800s, will never be fully documented.

NEXT STEPS

Because no historic studies exist, we will assess land use and vegetation changes in the San Francisquito watershed from historic topographic maps (1899) and digital, orthorectified air photos (1948, 1993, and 2002) that can be imported into the GIS. We will develop a classification for describing land uses in each sub-watershed for each time period. The results of these analyses will be reported with the Existing Conditions Analysis in a later report. They will also form part of the rapid sediment budget prepared as part of Task 5 (Sediment Analysis) by applying suitable erosion models or sediment production estimates to the areas falling into the different land use and vegetation community categories.

5. REFERENCES

Allardt, G. and C. Grunsky. 1888. Investigations of San Francisquito Creek. Submitted to Manzanita Water Company. Stanford, California. 20 p.

Anderson, R. 1908. Earth-flows at the time of the San Francisco Earthquake (Abstract). Bulletin of the Geological Society of America 18: 643.

Anderson, R.S. 1994. Evolution of the Santa Cruz Mountains, California. Journal of Geophysical Research 99(B10): 20.168 to 20.179.

Brabb, E. and E. Pampeyan. 1972. Preliminary map of landslides in San Mateo County, California. USGS Miscellaneous Field Studies Map MF-344. Scale 1:62,500.

Brabb, E., E. Pampeyan and M. Bonilla. 1972. Landslide susceptibility in San Mateo County, California. USGS Miscellaneous Field Studies Map MF-360. Scale 1:62,500.

Brabb, E., R. Graymer and D. Jones. 2000. Geologic map and map databases of the Palo Alto 30' X 60' Quadrangle, California. USGS Miscellaneous Field Studies Map MF-2332 and Pamphlet. 30 pp.

Brown, A.K. 1966. Sawmills in the Spanish Red Woods. San Mateo County Historical Association.

Brown, W. 1973. Erosion processes, fluvial sediment transport and reservoir sedimentation in a part of the Newell and Zayante Creek Bains, Santa Cruz County, California. USGS Open-File Report. Water Resources Division, Menlo Park, CA.

Brown, W. 1988. Historic setting of the storm: Perspectives on population, development, and damaging rainstorms in the San Francisco Bay region *in* Ellen, S. and G. Weiczorek (ed). Landslides, floods, and marine effects of the storm of January 3-5, 1982 in the San Francisco Bay Region, California. USGS Professional Paper 1434: 7-16.

Brown, W. and J. Jackson. 1973. Erosional and deposition provinces and sediment transport in the south and central part of the San Francisco Bay Region, California. USGS Miscellaneous Field Studies MF-515. 21 p. Pamphlet and Maps.

Buchan, L and M. Hayden. 2000. Inventory of Santa Clara Basin Stream Studies. Santa Clara Valley Urban Runoff Pollution Prevention Program.

Burgmann, R., R. Arrowsmith, T. Dumitru and R. McLaughlin. 1994. Rise and fall of the southern Santa Cruz Mountains, California from fission tracks, geomorphology and geodesy. Journal of Geophysical Research 99(B10): 20.181 to 20.202.

California Department of Fish and Game. 1974. San Francisquito Creek drainage streamflow measurements and fish sampling. Bear, Corte Madera and Los Trancos (July 31). Menlo Park.

California Department of Fish and Game. 1976. San Francisquito Creek drainage streamflow measurements and fish sampling. Walk of Bear Creek to San Francisquito Creek (June 24). Menlo Park.

California Department of Fish and Game. 1981. San Francisquito Creek drainage streamflow measurements and fish sampling. Walk of Upper San Francisquito Creek (June 30). Menlo Park.

Cannon, S. and S. Ellen. 1983. Rainfall that triggered abundant debris avalanches in the San Francisco Bay region, California, during the storm of January 3-5, 1982. USGS Open-File Report 83-10.

Cannon, S. and S. Ellen. 1985. Abundant debris avalanches, San Francisco Bay Region, California. California Geology 38(12): 267-72.

Chebanov, A. undated. Application of microgenesis level methods for San Francisquito Creek runoff model, San Francisquito Creek watershed, California, USA. Unpublished report to the United States Geological Survey.

Corps of Engineers. 1972. Survey Report on San Francisquito Creek, San Mateo and Santa Clara Counties, California, for Flood Control and Allied Purposes. U.S. Army Engineer District, San Francisco, California. 27 pp.

Coyote Creek Riparian Station. 1994. San Francisquito Creek creek survey summary 1993-94. San Francisquito Creek Coordinated Resource Management and Planning.

Coyote Creek Riparian Station. 1998. San Francisquito Creek upper watershed volunteer monitoring program (November 97 to October 98). San Francisquito Creek Coordinated Resource Management and Planning.

Creasey, C.L. 1988. Landslide damage: A costly outcome of the storm *in* Ellen, S. and G. Weiczorek (ed). Landslides, floods, and marine effects of the storm of January 3-5, 1982 in the San Francisco Bay Region, California. USGS Professional Paper 1434: 195-204.

Crippen, J.R. and A. Waananen. 1969. Hydrologic Effects of Suburban Development near Palo Alto, California. USGS Open-File Report. January 23. 35 pp.

Cummings, J. and Wm. Spangle & Associates (Compilers). 1975. Geologic Map: Town of Portola Valley, San Mateo County, California. Scale 1:6,000

Dickinson, W., J. Cummings and Wm. Cotton and Associates. 1992(?). Geologic Map: Town of Woodside, San Mateo County, California. Scale 1:7,200.

Ellen, S., M. Algus, S. Cannon, R. Fleming, P. Lahr, D. Peterson and S. Reneau. 1988. Description and mechanics of soil slip/debris flows in the storm. *in* Ellen, S. and G. Weiczorek (ed). Landslides, floods, and marine effects of the storm of January 3-5, 1982 in the San Francisco Bay Region, California. USGS Professional Paper 1434: 63-112.

Ellen, S., R. Mark, G. Wieczorek, C. Wentworth, D. Ramsey and T. May. 1997. Map showing principal debris-flow source areas in San Mateo County, California. USGS Open-File Report 97-745E. Sheet 7 of 11. Scale 1:125,000.

Ellen, S. and G. Weiczorek 1988. (eds). Landslides, floods, and marine effects of the storm of January 3-5, 1982 in the San Francisco Bay Region, California. USGS Professional Paper 1434. 310 pp and Plates.

Frey, C. 2001. Geomorphic Study of Searsville Lake Watershed, Portola Valley, California. M.Sc Thesis, San Jose State University. 137 pp.

Godt, J. (ed). 1999. Maps showing locations of damaging landslides caused by El Nino rainstorms, winter season 1997-98, San Francisco Bay region, California. USGS Miscellaneous Field Investigation MF-2325A-J. 11 p.

Helley, E, K. Lajoie, W. Spangle and M. Blair. 1979. Flatland deposits of the San Francisco Bay Region, California – their geology and engineering properties and their importance to comprehensive planning. USGS Professional Paper 943. 88 pp.

Inman, D. and S. Jenkins. 1999. Climate change and the episodicity of sediment flux of small California Rivers. Journal of Geology 107: 251-270.

Jayko, A, J. De Mouthe, K. Lajoie, D. Ramsey and J. Godt. 1999. Map showing locations of damaging landslides in San Mateo County, California, resulting from 1997-98 El Nino Rainstorms. USGS Miscellaneous Field Studies Map MF-2325-H.

Jayko, A., M. Rymer, C. Prentice, R. Wilson and R. Wells. 1998. The Scenic Drive Landslide Jan-Feb 1998, La Honda, San Mateo County, California. USGS Open-File Report 98-229. One Plate.

Keefer, D., R. Wilson, R. Mark, E. Brabb, W. Brown, S. Ellen, E. Hard, G. Weiczorek, C. Alger and R. Zatkin. 1987. Real-time landslide warning during heavy rainfall. Science 238: 921-925.

Keefer, D. (ed). 1998. The Loma Prieta, California, Earthquake of October 17, 1989 – Landslides. USGS Professional Paper 1551-C.

Keefer, D, G. Griggs, and E. Harp. 1998. Large landslides near the San Adreas fault in the Summit Ridge area, Santa Cruz Mountains, California in Keefer, D. (ed) The Loma Prieta, California, Earthquake of October 17, 1989 – Landslides. USGS Professional Paper 1551-C: p. C71-C128.

Kittleson, G., B. Hecht and D. Holmes. 1996. Sedimentation and channel dynamics of the Searsville Lake Watershed and Jasper Ride Biological Preserve, San Mateo County, California. Balance Hydrologics, Inc. June 30.

Knott, J.M. 1973. Effects of Urbanization on Streamflow and Sediment Discharge in the Colma Creek Basin, California. USGS Open-File Report. 54 pp.

Lawson, A.C (chairman). 1908. The California Earthquake of April 18, 1906: Report of the State Earthquake Investigation Commission. Carnegie Institute of Washington, Publication 87. 2 Volumes.

Lehre, A. 1982. Sediment budget of a small coast range drainage basin in North-Central California *in* Swanson, F.J., R. Janda, T. Dunne and D. Swanston (eds). Sediment Budgets and Routing in Forested Drainage Basins. USDA Forest Service. Pacific Northwest Forest and Range Experiment Station. General Technical Report PNW-41. p. 67-77.

Manson, M, D. Keefer, and M. McKittrick. 1992. Landslides and other geologic features in the Santa Cruz Mountains, California, resulting from the Loma Prieta Earthquake of October 17, 1989. California Division of Mines and Geology Open-File Report 91-05. 45 p and 15 plates. Scale 1:48,000.

Mark, R.K. 1992. Maps of debris-flow probability, San Mateo County, California. USGS Miscellaneous Investigations Series Map 1-1257-M. Scale 1:62,500.

Metzger, L. 2002. Streamflow Gains and Losses along San Francisquito Creek and, Characterization of Surface-Water and Ground-Water Quality, Southern San Mateo and Northern Santa Clara Counties, California, 1996-97. USGS Water-Resources Investigations Report 02-4078. 28 pp.

Napier, G, J. Perkins, R. Moreland, R. Mark and E. Brabb. 1992. Maps showing land use and land cover in Sam Mateo County, California. USGS Miscellaneous Investigations Map I-1257-L. Scale 1:62,500.

Nilsen, T, F. Taylor and R. Dean. 1976. Natural conditions that control landsliding in the San Francisco Bay region – an analysis based on data from the 1968-69 and 1972-73 rain seasons. USGS Bulletin 1424.

Nolan, K and D. Marron. 1985. Contrasts in stream-channel response to major storms in two mountainous areas of California. Geology 13(2): 135-138.

Nolan, K and D. Marron. 1988. Stream-channel response to the storm in Santa Cruz Mountains *in* Ellen, S. and G. Weiczorek (ed). Landslides, floods, and marine effects of the storm of January 3-5, 1982 in the San Francisco Bay Region, California. USGS Professional Paper 1434: 245-264.

Northwest Hydraulic Consultants and Jones & Stokes Associates. 1999. Family Farm Road Flood and Sediment Control Study. Phase 2 – Schematic Design Plan. Stanford University, Facilities Operation.

Northwest Hydraulic Consultants, Balance Hydrologics, Inc, H.T. Harvey & Associates, Jones & Stokes, Dr. Matt Kondolf and Dr. Jerry Smith. 2002. Searsville Lake Sediment Impact Study. Stanford University, Facilities Operation. 186 p and Appendices.

Owens, J., S. Chartrand and B. Hecht. 2002. Annual hydrologic record and sediment yield, Corte Madera Creek, Portola Valley, California: Data report for Water Year 2001. Balance Hydrologics, Inc for Stanford University, Facilities Operations Dept.

Owens, J., S. Chartrand and B. Hecht. 2002. Annual hydrologic record and sediment yield, Los Trancos Creek, Portola Valley, California: Data report for Water Year 2001. Balance Hydrologics, Inc for Stanford University, Facilities Operations Dept.

Pike, R., R. Graymer, S. Roberts, N. Kalman and S. Sobieszczyk. 2001. Map and map database of susceptibility to slope failure by sliding and earthflow in the Oakland area, California. USGS Miscellaneous Field Studies MF-2385. 37 p and Maps.

Phillips, R.L. 2000. Sedimentation of the flood tidal delta of San Francisquito Creek, South San Francisco Bay, California. US Geological Survey Presentation.

Reid, L. and T. Dunne. 1998. Rapid Evaluation of Sediment Budgets. Catena Verlag GMBH Geoecology Paperback. Germany. 164 pp.

Rodine, J.D, C. Price and others. 1975. Geology and movement potential within the Town of Portola Valley, California. Town of Portola Valley.

Royston, Hanamoto, Alley and Abey, Philip Williams & Associates, H.T. Harvey & Associates, Environmental Science Associates and Frederick T. Seher & Associates. 2000. San Francisquito Creek Bank Stabilization and Revegetation: Existing Conditions Report. Prepared for City of Menlo Park, City of Palo Alto, City of East Palo Alto, Santa Clara Valley Water District and County of San Mateo. 121 pp.

Santa Clara Basin Watershed Management Initiative (SCBWMI). 2000 (May). Watershed management plan. Volume One: Watershed characteristic report. 165 pp.

Smith, J.J. and D. Harden. 2001. Adult Steelhead passage in the Bear Creek Watershed. San Francisquito Watershed Council. 65 p.

Smith, T. and E. Hart. 1982. Landslides and related storm damage: January 1982, San Francisco Bay Region. California Geology 35(July): 139-152.

Smith, T. 1988. A method for mapping relative susceptibility to debris flows, with an example from San Mateo County *in* Ellen, S. and G. Weiczorek (ed). Landslides, floods, and marine effects of the storm of January 3-5, 1982 in the San Francisco Bay Region, California. USGS Professional Paper 1434: 195-204.

Stanger, F.M. 1967. Sawmills in the Redwoods: Logging on the San Francisco Peninsula, 1849-1967. San Mateo County Historical Association.

Swanston, D.N. and F.J. Swanston. 1976. Timber harvesting, mass erosion, and steepland forest geomorphology in the Pacific Northwest in Coates, D.R. (ed). Geomorphology and Engineering. Dowden, Hutchinson and Ross. Stroudsburg, PA. p. 199-221.

Taylor, F. and E. Brabb. 1972. Maps showing distribution and cost by counties of structurally damaging landslides in the San Francisco Bay region, California, winter of 1968-69. USGS Miscellaneous Field Studies Map MF-327. Scales 1:500,000 and 1:1,000,000.

Taylor, F., T. Nilsen and R. Dean. 1975. Distribution and costs of landslides that have damaged manmade structures during the rainy season of 1972-73 in the San Francisco Bay region, California. USGS Miscellaneous Field Studies Map MF-679. Scales 1:500,000 and 1:1,000,000.

United States Geologic Survey. 2003. Western Geoscience Center GIS Database for San Francisquito Creek (http://wgsc.wr.usgs.gov/sfcreek/).

Varnes, D.J. 1978. Slope movement types and processes *in* Schuster, R.L. and R.S. Krizek (eds). Landslides: Analysis and Control. US National Academy of Sciences. Transportation Research Board Special Report 176. p. 11-33.

Wentworth, C.M. 1986. Maps of debris flows evident after the storms of December 1955 and January 1982, Montara Mountain Area, California. USGS Open-File Map 86-363. Scale 1:24,000

Wentworth, C., S. Ellen, V. Frizzell, Jr. and J. Schlocker. 1985. Map of Hillside Materials and Description of Their Engineering Character, San Mateo County, California. USGS Miscellaneous Investigations Series Map I-1257-D. Two Sheets.

Wentworth, C., S. Graham, R.J. Pike, G. Buekelman, D. Ramsey and A. Barron. 1997. Summary of distribution of slides and earth flows in San Mateo County, California. USGS Open-File Report 97-745C. 10 p and 11 sheets.

Wieczorek, G.F. 1982. Map showing recently-active and dormant landslides near La Honda, central Santa Cruz Mountains, California. USGS Miscellaneous Field Studies Map MF-1422. Scale 1:4,800.

Weiczorek, G.F., E. Harp and R. Mark. 1982. Debris flows and other landslides in San Mateo, Santa Cruz, Contra Costa, Alameda, Napa, Solano, Lake and Yolo Counties, and factors influencing debris flow distribution *in* Ellen, S. and G. Weiczorek (eds). Landslides, floods, and marine effects of the storm of January 3-5, 1982 in the San Francisco Bay Region, California. USGS Professional Paper 1434: 133-161.

Wieczorek, G.F and J. Sarmiento. 1983. Significance of storm intensity-duration for triggering of debris flows near La Honda, California. Geological Society of America Abstracts with Programs 15(5): 289.

Wilson, R.C. and A. Jayko. 1997. Preliminary maps showing rainfall thresholds for debris-flow activity, San Francisco Bay region, California. USGS Open-File Report 97-745 F, 20 pp (scale 1:275,000).

Youd, T. and S. Hoose. 1978. Historic ground failures in northern California triggered by earthquakes. USGS Professional Paper 993. 177 p.

Table 1. Historic Topographic Maps

Map Name	Author	Edition	Surveyed	Scale	Notes
Palo Alto, California	USGS	1899	1895	1:62,500	
Half Moon Bay, California	Corps	1941	1940	1:62,500	
Palo Alto, California	Corps	1942	1937-40	1:50,000	revised 1947
Half Moon Bay, California	Corps	1942	1937-40	1:50,000	revised 1948
Palo Alto, California	USGS	1948	1937-40	1:62,500	revised 1961
Palo Alto, California	USGS	1953	1948	1:24,000	revised 1961, 1968, 1973, 1991, 1997
Half Moon Bay, California	USGS	1961	1948-53	1:62,500	
Woodside, California	USGS	1953	1948	1:24,000	revised 1961, 1968, 1973, 1991, 1997
La Honda, California	USGS	1955	1953	1:24,000	revised 1961, 1968, 1991
Mindego Hill, California	USGS	1955	1953	1:24,000	revised 1961, 1968, 1991, 1997

Notes: USGS = U.S. Geological Survey
Corps = U.S. Army Corps of Engineers, Army Map Service

Table 2. Physical Characteristics of the San Francisquito Creek Subwatersheds

Subwatershed	**Sub-subwatershed**	**Area (acres)**	**Stream lengths (ft)**	**Average stream slope (%)**	**Minimum elevations (ft)**	**Maximum elevation (ft)**	**Watershed slope (%)**	**Length of Roads (miles)**	**Dominant Geologic Units [1]**
San Francisquito Creek Watershed	All Subwatersheds	30127	434997	11.7	0	7843	14.5	440.7	Tw, QTsc, Qpaf
San Francisquito Creek (Main Stem)	SF-1 to SF-12	8577	82160	5.5	0	2100	7.5	207	Qpaf, Tw, Qpoaf
Los Trancos Creek	LT-1 to LT-7	4870	87229	11.6	485	7166	23.4	50.7	fg, QTsc, Tw
Corte Madera Creek	CM-1 to CM-12	4366	62765	15.6	1070	7843	26.4	50.9	Tla, QTsc, Tw
West Union Creek	WUC-1 to WUC-11	3575	73248	17.1	1155	7294	27.8	25.0	Tw
Bear Gulch	BG-1 to BG-3	2250	38643	14.8	3895	7333	28.9	16.3	Tw, Tla, QTsc
Bear Creek	BC-1 and BC-2	1582	24652	5.0	771	2743	11.9	28.3	QTsc, Tw, fg
Sausal Creek	SC-1 to SC-6	1547	30225	13.5	1067	5767	23.5	20.4	Tw, Tb, Tp
Alambique Creek	AC-1 Alambique Creek	1492	13524	19	1067	6980	28.4	18.8	Tw, Tla, Qpoaf
Westridge Creek	SL 1 and SL 2	1078	14131	12.0	847	2365	17.2	11.5	fg, Tw, QTsc
Martin Creek	MC-1 Martin Creek	790	8420	19	1079	5502	27.4	11.8	Tw, Tb, Tla

1. Geologic formations described in Brabb *et al* (2000).

Table 3: Reported Dates of Abundant Landsliding in the San Francisco Bay Region [1]

Date or Period	References	Comment
December 1861 to January 1862	Brown (1988)	flooding; landslide damage in SF Creek watershed; see Kittleson et al (1996)
Earthquakes of October 8,1865 and October 21, 1868	Youd and Hoose 1978; Marshall 1990 in Keefer (1998)	Landslides known to have occurred in Santa Cruz Mountains; documentation is fragmentary
Winter of 1866-67	Marshall (1990) in Keefer (1998)	Landslides and flooding in Central Santa Cruz Mtns
Winter of 1879	Brown (1988)	No discussion of San Francisquito Watershed
Winter of 1881	Brown (1988)	No discussion of San Francisquito Watershed
Winter of 1889-90	San Mateo County Times Newspaper, May 16, 1967 (Mrs. D. Regnery)	Large Landslide from Vista Verde Area into Los Trancos Creek
Winter of 1895	Brown (1988)	No discussion of San Francisquito Watershed
San Francisco Earthquake of 1906	Lawson et al 1908; Anderson 1908. Also Youd and Hoose (1978) and Keefer (1984)	Maps and discussion of San Francisquito Creek in Youd and Hoose (1978). Kittleson et al (1996) quote an early report on extensive disturbance of Corte Madera Ck by landslides. Anderson notes debris flows around Bay.
Winter of 1906-07	Marshall (1990) in Keefer (1998); Smith and Hart (1982)	Landslides along roads and railroads in Central Santa Cruz Mountains
March 1911	Brown (1988)	No discussion of San Francisquito Watershed
February 1914	Brown (1988)	No discussion of San Francisquito Watershed
February 1927	Brown (1988)	No discussion of San Francisquito Watershed
December 1937 to March 1938	Brown (1988) and Brown and Jackson (1973)	No discussion of San Francisquito Watershed
February 1940	Brown (1988)	No discussion of San Francisquito Watershed
January 1943	Brown (1988)	No discussion of San Francisquito Watershed
Winter of 1949-50	Smith and Hart (1982)	No discussion of San Francisquito Watershed
December 1951 to January 1952	Brown (1988)	No discussion of San Francisquito Watershed
December 1955 to January 1956	Smith and Hart (1982); Radbruch and Weiler (1963)	Flooding and storm damage in San Francisquito Creek. No specific discussion of landslides or debris flows
February and April 1958	Brown (1988)	No discussion of San Francisquito Watershed
Winter of 1961-62	Smith and Hart (1982)	No discussion of San Francisquito Watershed
October 1962 to February 1963	Brown (1988) and Smith and Hart (1982); Radbruch and Weiler 1963	suspended sediment measured at USGS gage on SF Creek
December 1964 to February 1965	Brown (1988) and Smith and Hart (1982)	suspended sediment measured at USGS gage on SF Creek
January 1967	Brown (1988); Smith and Hart (1982)	suspended sediment measured at USGS gage on SF Creek
January to March 1969	Brabb et al (1972); Brown and Jackson (1973)	damaging landslides in San Francisquito Watershed inventoried; suspended sediment measured at gage on SF Creek

Table 3: Reported Dates of Abundant Landsliding in the San Francisco Bay Region [1]

Date or Period	References	Comment
December 1969 to March 1970	Brown (1988)	No discussion of San Francisquito Creek
January to April 1973	Nilsen et al (1975); Smith and Hart (1982)	damaging landslides in San Francisquito Watershed inventoried
December 1973 to February 1974	Brown (1988); Smith and Hart (1982)	No discussion of San Francisquito Creek
December 1977 to March 1978	Weiczorek 1982; Smith and Hart (1982)	No discussion of San Francisquito Creek
Winter of 1979-80	Weiczorek 1982	Landslides observed near La Honda; no discussion of San Francisquito Creek
January 1982	Weiczorek et al 1988; Smith and Hart 1982	debris flows and damaging landslides in San Francisquito Creek. Detailed maps of debris flow distribution.
Loma Prieta Earthquake of 1989	Keefer 1998; Manson et al 1989	Loma Prieta Earthquake landslides; none mapped in San Francisquito Watershed
Winter of 1995-96	Kittleson et al (1996)	Unusual bedload transport on Los Trancos; no inventory of sediment sources. Alpine Road failure
El Nino storms of 1997-98	Godt (ed) 1999; Frey 2000	damaging landslides inventoried; other failures noted, mapped by Frey (2000)

1. Early dates and references from Brown (1988) or Smith and Hart (1982). Brown's analysis based on damaging rainstorms; Smith and Hart on reported debris flow incidence.

Table 4: Summary of the Numbers of Damaging Landslides Observed in San Francisquito Creek Watershed

Source	Landslide Description	Number of Landslides by Sub-Watershed					Comment
		Searsville Lake	Corte Madera	Los Trancos	Bear	San Francisquito	
Brabb and Pampeyan (1972)	Active deep-seated slides and flows as identified by Public Agencies	10	0	0	0	0	No landslides in fill included; data base fragmentary and known to be incomplete. Slides near Neils & Bull Run Cks
Brabb and Pampeyan (1972)	Active deep-seated slides and flows mapped in field	2	0	0	0	3	prior to 1970 or so. More than 500 feet in maximum dimension
Taylor and Brabb (1972)	Damaging landslides from the winter of 1968-69	1	3	0	1	2 (?)	Small scale map; difficult to identify where landslides occurred
Taylor, Nilsen and Dean (1975)	Damaging landslides from the winter of 1972 -73	0	0	0	0	0	Small scale map; difficult to identify where landslides occurred
Creasey in Ellen et al (1988)	Damaging landslides from the January 3-5 1982 storm	5	2	0	11	1	As reported by public agencies, including debris flows and landslides. Mostly road damage
Manson et al (1989)	Landslides resulting from the 1989 Loma Prieta Earthquake	0	0	0	0	0	None observed in San Francisquito Creek watershed
Jayko et al (1999)	Damaging landslides from the winter of 1997-98	3	0	1	0	0	Many more landslides observed but not inventoried. Digital file for each damaging landslide
Total Recorded		**21**	**5**	**1**	**12**	**6**	

Table 5: Summary of Debris Flow and Other Slope Failure Inventories in San Francisquito Creek Watershed

		Slope Failure Characteristics by Sub-Watershed					
Source	**Characteristic**	**Searsville Lake**	**Corte Madera**	**Los Trancos [1]**	**Bear**	**San Francisquito**	**Comment**
	Watershed Area (km^2)	19	18	20	30	35	
January 1982 Storm							
Weiczorek et al (1988)	Numbers of Debris Flows	46	8	11	27	0	Mostly along La Honda Rd near Alambique Ck
	Portion Entering Streams	44%	67%	25%	44%	N/A	estimated from position of debris flow tracks on 1:62,500 map; very approximate
	Typical Track Length (feet)	less than 500	less than 500	less than 500	less than 500	N/A	approximate only; from 1:62,500 map
	Maximum Length (feet)	less than 500	about 750	less than 500	about 500	N/A	approximate only; from 1:62,500 map
	Typical Position	road cut and fill	lower slopes of steep tributaries	Valley sides	lower slopes of steep tributaries	N/A	estimated from position of debris flow tracks on 1:62,500 map
	Debris flow Concentration (#/km^2)	2.5	0.4	0.6	0.9	0.0	calculated by dividing total observed flows by subwatershed area
	Concentration Ranking	sparse	sparse	sparse	sparse	sparse	sparse is less than 5/km^2
El Nino Storms of 1997-98							
Frey (2000)	Number of Small Landslides	159	297	N/A	N/A	N/A	from GIS digital map
	Total Area of Small Landslides (acres)	8.76	18.26	N/A	N/A	N/A	from GIS digital map
	Average Area (yd^2)	270	300	N/A	N/A	N/A	Calculated by dividing total area by number of slides
	Large Landslides observed entering Streams	9	21	N/A	N/A	N/A	Source and dimensions of large slides not reported

1. Only includes the portion of Los Trancos Creek that lies in San Mateo County for portion entering streams, typical track length, maximum length and typical position.

Table 6: Summary of Erosion Characteristics of the San Francisquito Creek Watershed

Subwatershed	Sub-subwatershed	Area (acres)	Average Basin Slope (%)	% streams with high sediment production[1]	% streams with severe bank erosion[2]	# of landslides (small/large)[3]	% stream length near landslide zone[4]	# of debris flows[5]	% area with erosive geology[6]	% stream length with erosive slopes[7]
Corte Madera Creek	CM-1 to CM-12	4366	26	38	50.1	335 / 21	56	14	85	30%
Alambique Creek	AC-1	1492	28.4	18.7	23.2	47 / 0	32	18	86	39%
Martin Creek	MC-1	790	27.4	11.1	18.7	25 / 3	91	16	56	51%
Sausal Creek	SC-1 to SC-6	1547	23.5	8.2	6.5	34 / 6	37	6	65	28%
Westridge Creek	SL 1 and SL 2	1078	17.2	0	0	1 / 0	4	0	38	13%
West Union Creek	WUC-1 to WUC-11	3575	27.8	--	--	--	7	19	93	35%
Bear Gulch	BG-1 to BG-3	2250	28.9	--	--	--	21	7	94	31%
Bear Creek	BC-1 and BC-2	1582	11.9	--	--	--	0	1	73	0%
Los Trancos Creek	LT-1 to LT-7	4870	23.4	--	--	--	22	11	36	18%
San Francisquito Creek	SF-1 to SF-12	8577	7.5	--	--	--	3	0	27	4%

1 = from Frey (2001) - calculated by dividing streams with classes 1 and 2 by total stream length
2 = from Frey (2001) - calculated by dividing streams with severely eroding banks by total stream length
3 = from Frey (2001) - refers to number of landslides bordering the creek channel
4 = from USGS (Wentworth et al., 1997)
5 = from USGS (Wentworth et al., 1997)
6 = Erosive geologies determined from Frey (2001), Wieczorek et al. (1989), and Balance Hydrologics (1996) and consist of Purisima Formation (Tp), Santa Clara Formation (Qtsc), Vaqueros Formation (Tvq), San Lorenzo Formation and Lambert Shale (Tls, Tst, Tla, Tmb), Whiskey Hill Formation (Tw, Tws), Monterey Formation (Tm),
7 = slopes ranging from 360m/km to 580m/km were found to contain the highest percentage of high sediment producting streams by Frey (2001)

Table 7: Summary of Debris Flow and Slides Observed in the Air Photo Inventory [1]

Approximate Age [2]	Characteristic	Slope Failures by Sub-Watershed					Comment
		Searsville Lake	Corte Madera	Los Trancos	Bear	San Francisquito	
	Watershed Area (km^2)	19	18	20	30	35	
Fresh failures, assumed to have occurred in 1997-98 or later	Number Observed	3	26	12	1	0	
	Total Area (m^2)	900	40700	8300	300	0	
	Average Area (m^2)	300	1565	692	300	N/A	
	Percent of Failures from Roads or other disturbances	100%	38%	35%	0%	N/A	Failures in road fill, cut or related to road drainage
Shrub growth on failure track, assumed to be less than ten years old but before 1997-98	Number Observed	8	26	13	7	0	
	Total Area (m^2)	11000	38600	15800	6500	0	
	Average Area (m^2)	1375	1485	1215	929	N/A	
	Percent of Failures from Roads or other disturbances	5%	33%	32%	31%	N/A	Failures in road fill, cut or related to road drainage
Trees on failure track, assumed to be 10 to 30 years old	Number Observed	7	19	2	7	0	
	Total Area (m^2)	25900	66200	3000	9200	0	
	Average Area (m^2)	3700	3484	1500	1314	N/A	
	Percent of Failures from Roads or other disturbances	42%	54%	33%	100%	N/A	Failures in road fill, cut or related to road drainage
Track substantially revegetated but still apparent, assumed to be more than 30 years old.	Number Observed	4	10	1	1	0	
	Total Area (m^2)	11900	52100	1000	3300	0	
	Average Area (m^2)	2975	5210	1000	3300	N/A	
	Percent of Failures from Roads or other disturbances	42%	38%	0%	0%	N/A	Failures in road fill, cut or related to road drainage

1. Color Photos roll number is WAC-C-00-CA, dated March 22, 2000; nominal scale of 1:22,000. Minimum failure size inventoried was about 300 m^3 (400 yd^3).
2. Ages estimated from re-growth of vegetation and are only approximate. Inventory of older failures assumed to be incomplete because of vegetation regrowth obscuring tracks of smaller failures.

Table 9: Annual Transport Volumes and Denudation Rates in San Francisquito Creek Watershed

A. Searsville Lake Deposition

Period	Annual Deposition (ac-ft/yr)	Watershed Area (km^2)		Denudation Rate (mm/year) [1]		
		Searsville	Corte Madera	Total	Corte Madera [2]	Remainder
Searsville Lake Deposition						
1892 to 1913	17.4	35.9	16.1	0.66	1.20	0.23
1913 to 1929	3.6	35.9	16.1	0.14	0.25	0.05
1929 to 1946	7.2	35.9	16.1	0.27	0.50	0.09
1946 to 1995	7.1	35.9	16.1	0.27	0.49	0.09
1995 to 2000	23.5	35.9	16.1	0.89	1.62	0.31
Average	9.4	35.9	16.1	0.36	0.65	0.12
Total Searsville Lake and Fan Deposition						
1995 to 2000	43.4	35.9	16.1	1.49	2.69	0.51

1. Assumes that the annual deposition represents 90% of total; 10% over dam crest (see **nhc** *et al* 2002)
2. Assumes that Corte Madera provides 81% of total load (see **nhc** *et al* 2002)
3. Assumes that 1 dam^3 = 1.23 acre-feet

B. Annual Suspended Load (Brown and Jackson 1973)

Period	Annual Transport (tons)	Annual Volume [4] (ac-ft)	Watershed Area (km^2) [5]	Denudation Rate (mm/year) [5]		
				Total	Bear	Los Trancos
1962	1,880	0.9	49.7	0.01	0.01	0.01
1963	18,700	8.6	49.7	0.14	0.15	0.13
1964	1,100	0.5	49.7	0.01	0.01	0.01
1965	10,500	4.8	49.7	0.08	0.08	0.07
1966	1,100	0.5	49.7	0.01	0.01	0.01
1967	50,600	23.2	49.7	0.38	0.40	0.35
1968	2,700	1.2	49.7	0.02	0.02	0.02
1969	34,200	15.7	49.7	0.26	0.27	0.23
Total	120,800					
Average Suspended Load from Bear and Los Trancos Creeks [6]						
	15,100	6.9	49.7	0.11	0.12	0.10

4. Assumes 1.35 tons/yd^3; 1,613 yd^3/acre-foot
5. Assumes area of Los Trancos watershed is 7.61 mi^2; that of Bear Creek is 11.57 mi^2
6. Average suspended load is average for 1962 to 1969 at the San Francisquito Creek gauge; 64% from Bear; 36% from Los Trancos.

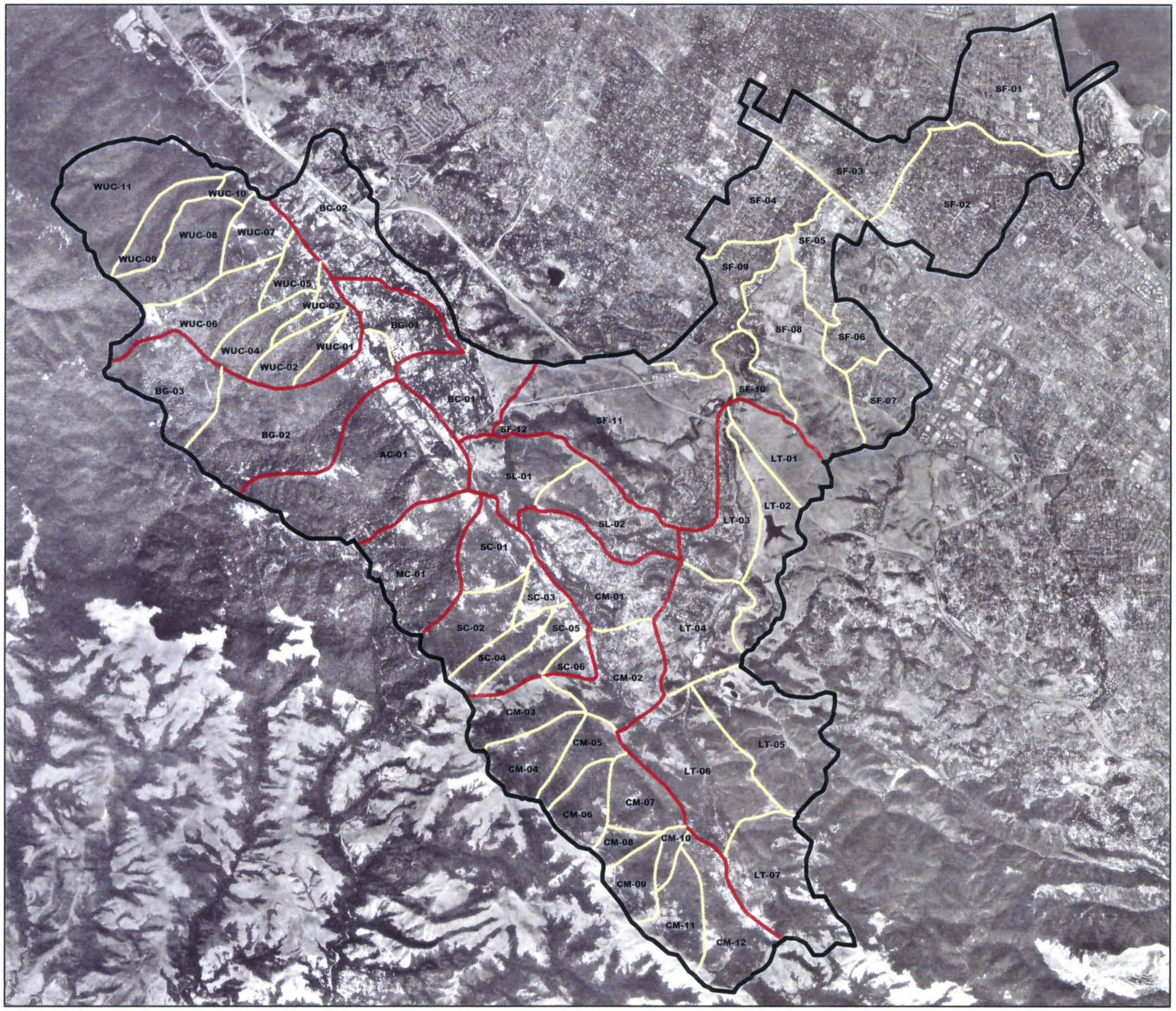
Table 10. Summary of Historic Road Characteristics of the San Francisquito Creek Subwatersheds [1]

Subwatershed	Sub-subwatershed	Area (acres)	1868-99			1953-55			1968		
			Paved Roads (miles)	Unpaved Roads (miles)	# of bridge crossings	Paved Roads (miles)	Unpaved Roads (miles)	# of bridge crossings	Paved Roads (miles)	Unpaved Roads (miles)	# of bridge crossings
San Francisquito Creek Watershed	All Subwatersheds	30127	--	122.9	11	247.5	68.6	123	335	90.8	123
San Francisquito Creek (Main Stem)	SF-1 to SF-12	8577	--	56.6	6	149.2	9.1	24	191.6	13.9	24
Los Trancos Creek	LT-1 to LT-7	4870	--	10.8	3	16.9	8.3	26	31.0	15.4	26
Corte Madera Creek	CM-1 to CM-12	4366	--	16.9	--	16.2	10.2	13	28.3	13.8	13
West Union Creek	WUC-1 to WUC-11	3575	--	13.7	1	10.8	9.6	24	15.3	10.1	24
Bear Gulch	BG-1 to BG-3	2250	--	4.3	1	8.6	6.9	7	8.8	7.4	7
Bear Creek	BC-1 and BC-2	1582	--	6.3	--	20.4	1.1	10	25.8	2.3	10
Sausal Creek	SC-1 to SC-6	1547	--	5.4	--	9.3	6.3	11	11.2	8.5	11
Alambique Creek	AC-1 Alambique Creek	1492	--	5.7	--	5.1	11.3	4	7.2	12.1	4
Westridge Creek	SL 1 and SL 2	1078	--	0.8	--	3.8	3.4	2	6.9	4.4	2
Martin Creek	MC-1 Martin Creek	790	--	2.4	--	7.2	2.4	2	8.9	2.9	2

1 - All road lengths were measured from historic maps and are considered accurate to within +/-15%

Table 11. Summary of Existing Road Characteristics of the San Francisquito Creek Subwatersheds

Subwatershed	Sub-subwatershed	Area (acres)	Length of roads (miles)		Length of roads within given slope class (miles)						Length of roads within erosive geologies (miles)	
					0 - 20 degrees		20 - 35 degrees		35+ degrees			
			Paved	Unpaved	paved	unpaved	paved	unpaved	paved	unpaved	paved	unpaved
San Francisquito Creek Watershed	All Subwatersheds	30127	350.5	89.7	302.3	47.3	40.1	29	8.1	13.4	118.7	56.7
San Francisquito Creek (Main Stem)	SF-1 to SF-12	8577	193.6	13.1	189.3	12.2	3.6	0.8	0.7	0.1	19.9	2.7
Los Trancos Creek	LT-1 to LT-7	4870	35.9	14.8	26.0	9.5	9.2	3.9	0.7	1.4	14.0	3.2
Corte Madera Creek	CM-1 to CM-12	4366	35.8	15.0	23.4	5.5	9.1	6.9	3.3	2.6	27.6	13.0
West Union Creek	WUC-1 to WUC-11	3575	15.5	9.5	9.3	5.3	5.0	3.3	1.2	0.9	11.7	8.8
Bear Gulch	BG-1 to BG-3	2250	8.8	7.5	8.1	1.9	0.5	2.6	0.2	3.0	7.5	7.4
Bear Creek	BC-1 and BC-2	1582	26.0	2.3	23.4	2.1	2.3	0.2	0.3	--	14.1	1.9
Sausal Creek	SC-1 to SC-6	1547	11.8	8.6	8.0	3.2	3.5	4.4	0.4	1.0	8.3	5.8
Alambique Creek	AC-1 Alambique Creek	1492	7.2	11.6	4.5	2.9	2.2	4.9	0.5	3.8	5.4	11.0
Westridge Creek	SL 1 and SL 2	1078	7.0	4.4	6.0	4.0	1.0	0.3	--	0.1	5.2	2.1
Martin Creek	MC-1 Martin Creek	790	8.9	2.9	4.3	0.7	3.7	1.7	0.8	0.5	5.0	0.8



Legend

CM-03 Sub-sub-watershed label

Sub-sub-watershed boundary

Sub-watershed boundary

Watershed boundary

Source: USGS 1993 Palo Alto, CA DOQ.

N

3000 0 3000 6000 9000 12000 Feet

Scale: 1 inch = 6000'

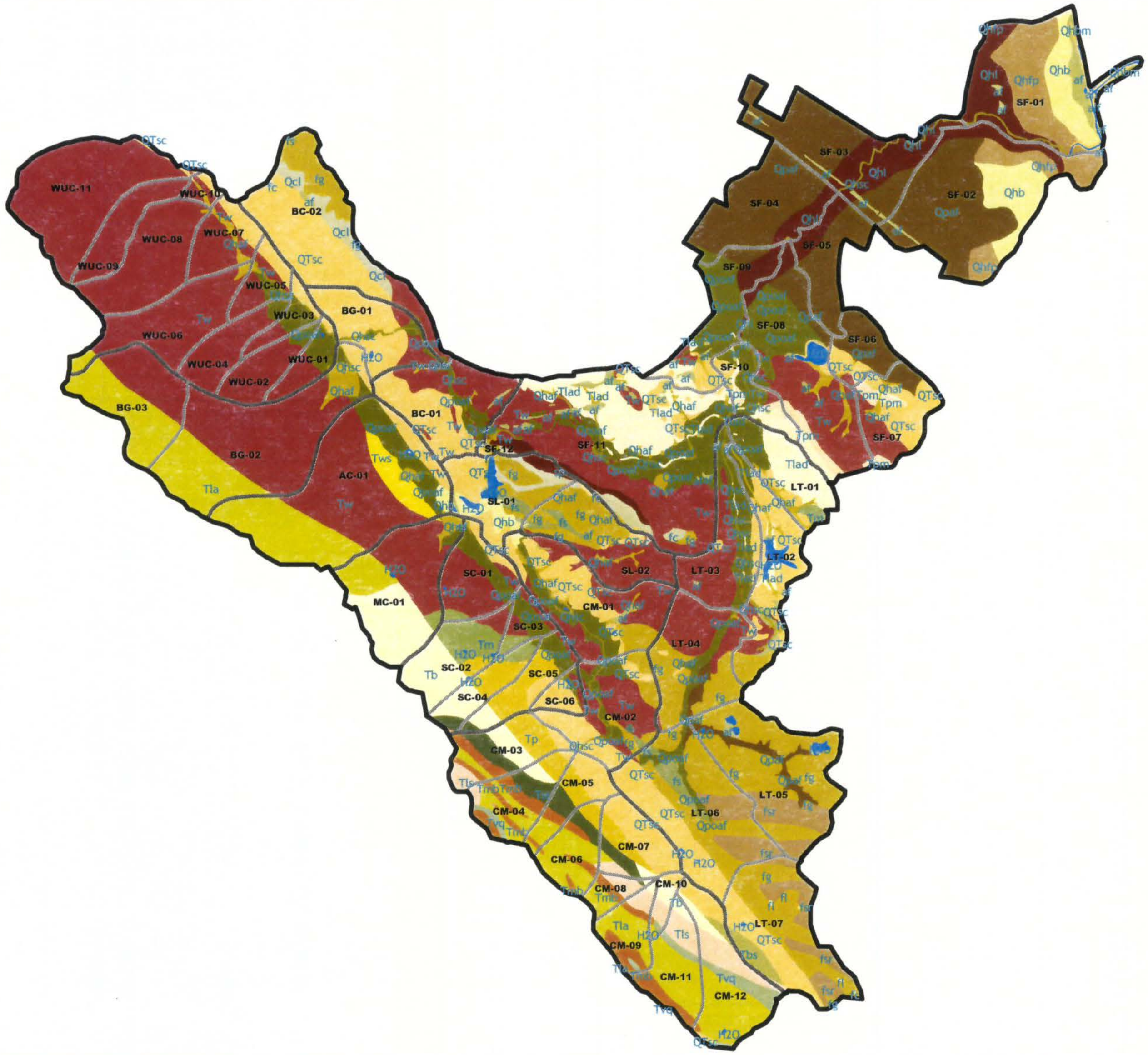
Figure 1
Watershed and Sub-Watershed Boundaries
San Francisquito Creek Basin

San Francisquito Creek Watershed Analysis and Sediment Reduction Plan

San Francisquito Creek Joint Powers Authority

nhc
northwest hydraulic consultants, inc.
3950 industrial boulevard, suite 100c
west sacramento, california 95691
(916) 371-7400

Jones & Stokes



Legend

fl 🟨 fs 🟩 fsr 🟧 sp 🟥	Geologic unit
CM-03	Sub-sub-watershed label
╱╲╱	Sub-sub-watershed boundary
╱╲╱	Sub-watershed boundary
▭	Watershed boundary

Source: USGS Palo Alto, CA geologic map database (2000).

N

3000 0 3000 6000 9000 12000 Feet

Scale: 1 inch = 6000'

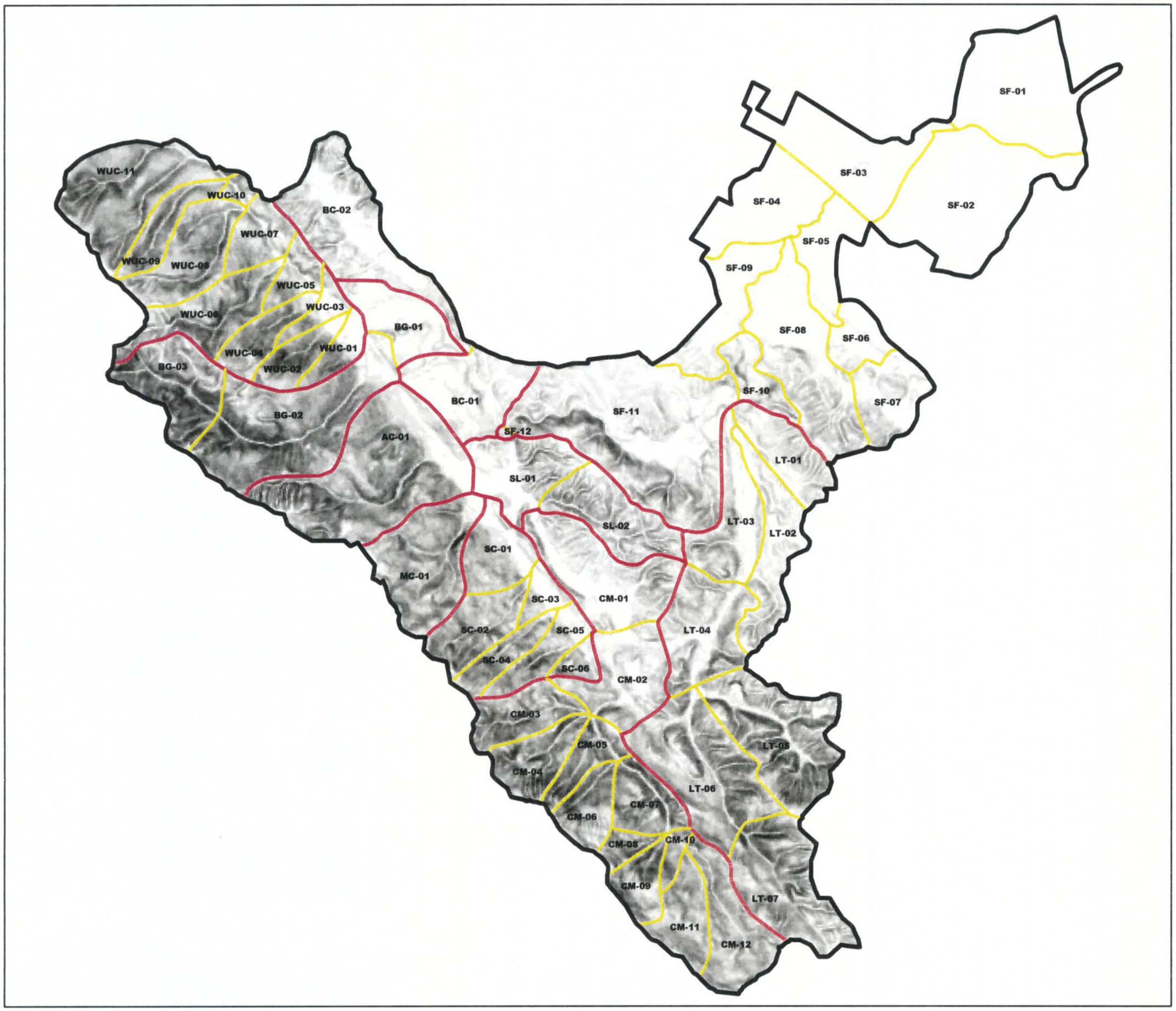
Figure 2
Geology
San Francisquito Creek Basin

San Francisquito Creek Watershed Analysis and Sediment Reduction Plan

San Francisquito Creek Joint Powers Authority

nhc northwest hydraulic consultants, inc.
3950 industrial boulevard, suite 100c
west sacramento, california 95691
(916) 371-7400

Jones & Stokes



Source: USGS OF 98-766.

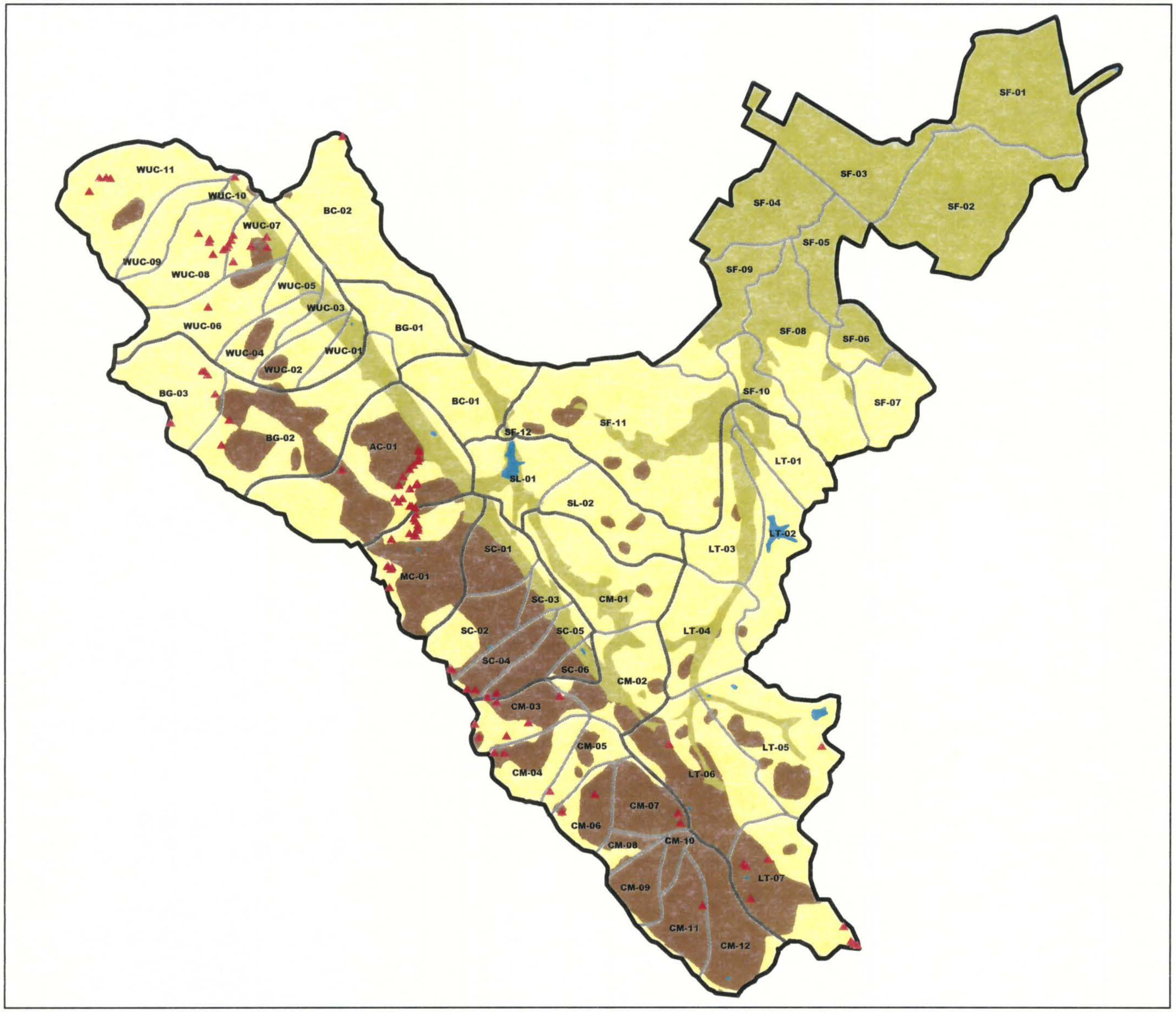
Figure 3
Slope
San Francisquito Creek Basin

San Francisquito Creek Watershed Analysis and Sediment Reduction Plan

San Francisquito Creek Joint Powers Authority

nhc northwest hydraulic consultants, inc.
3950 industrial boulevard, suite 100c
west sacramento, california 95691
(916) 371-7400

Jones & Stokes



Legend

▲	Debris flow source areas
🟨	Few landslides
🟫	Mostly landslides
🟩	Surficial deposits
🟦	Water
CM-03	Sub-sub-watershed label
╱╲╱	Sub-sub-watershed boundary
╱╲╱	Sub-watershed boundary
▭	Watershed boundary

Source: USGS OF 97-745C, 97-745E.

N

3000 0 3000 6000 9000 12000 Feet

Scale: 1 inch = 6000'

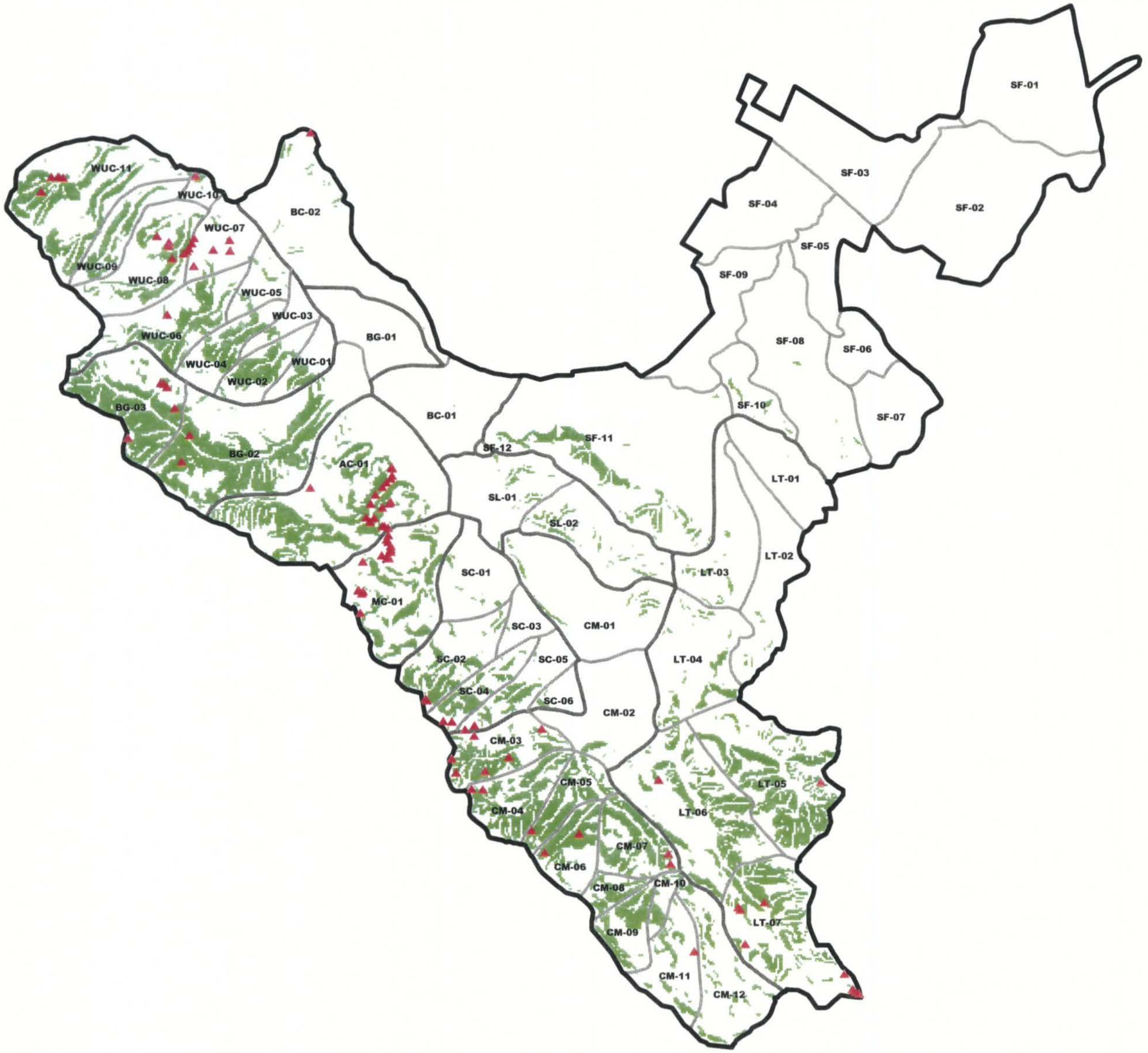
Figure 4
Landslides
San Francisquito Creek Basin

San Francisquito Creek Watershed Analysis and Sediment Reduction Plan

San Francisquito Creek Joint Powers Authority

nhc northwest hydraulic consultants, inc.
3950 industrial boulevard, suite 100c
west sacramento, california 95691
(916) 371-7400

Jones & Stokes



Legend

▲ Approximate sources of debris-flows triggered during the storm of January 1982

🟩 Principal predicted debris-flow source areas

CM-03 Sub-sub-watershed label

Sub-sub-watershed boundary

Sub-watershed boundary

▭ Watershed boundary

Source: USGS OF 97-745E.

Scale: 1 inch = 6000'

Figure 5
Debris-Flows
San Francisquito Creek Basin

San Francisquito Creek Watershed Analysis and Sediment Reduction Plan

San Francisquito Creek Joint Powers Authority

nhc northwest hydraulic consultants, inc.
3950 industrial boulevard, suite 100c
west sacramento, california 95691
(916) 371-7400

Jones & Stokes

Table A1: Historic Data Collection Summary and Data Gaps

	Studies or Data Bases	Geographic Extent of Study	Summary or Conclusions	Missing Information or Data Gaps	Relevance to Study

	Studies or Data Bases	Geographic Extent of Study	Summary or Conclusions	Missing Information or Data Gaps	Relevance to Study
Watershed Physiography Data Bases	Western Geoscience Center http://wgsc.wr.usgs.gov/sfcreek/	San Francisquito Creek Watershed	Provides GIS data base for the watershed including subwatershed boundaries, stream network, geologic formations, slopes, and elevations	Subwatershed boundaries along SF Creek are to be updated	Basic information for physiographic analysis of watershed
Landslide and Debris Flow Data Bases	Brown, 1988, "Historic Setting of the Storm: perspectives on population, development and damaging rainstorms in the San Francisco Bay Region" in Ellen and Weiczorek (eds) US PP 1434	San Francisco Bay Region	Provides an assessment of those years when abundant slope failures may have occurred in the San Francisco Bay Region	Lacks dates for landslides, number of failures or volumes contributed to streams	Provides a historic review of landslide and debris flow occurrences to 1982.
	Smith and Hart, 1982, "Landslides and related storm damage: January 1982, San Francisco Bay Region", California Geology 35	San Francisco Bay Region	Describes those landslides leading to fatalities and provides of history of years when abundant failures have occurred in the past	Lacks dates for landslides, number of failures or volumes contributed to streams	Provides a historic review of landslide and debris flow occurrences to 1982.
	Brabb and Pampeyan, 1972. "Preliminary map of landslides in San Mateo County, California" MF-344	San Mateo County (covers majority of San Francisquito Creek watershed)	Map of large landslide deposits visible on air photographs and active landslides identified during fieldwork or by Public agencies. Shows numbers and areas of landslide deposits.	Lacks dates for landslides and the volumes contributed to streams	Shows active landslides from the late 1960s.
	Rodine, J.D. 1975. "Geology and movement potential within the town of Portola Valley, California"	Town of Portola Valley	Detailed geologic map showing landslides with interpreted hazards and discussion of land surface instability. Based partly on above study	Updates Brabb and Pampeyan, lacks dates for landslides and volumes contributed to streams	Not very useful for sediment budget
	Cummings, J. and Wm. Spangle & Associates (Compilers), 1975. "Geologic Map: Town of Portola Valley, San Mateo County, California"	Town of Portola Valley	See above	See above	See above
	Dickinson *et al*, 1992(?). "Geologic Map: Town of Woodside, San Mateo County, California."	Town of Woodside	Detailed geologic map showing landslides and interpreted hazards	Lacks dates for landslides and volumes contributed to streams	See above

	Studies or Data Bases	Geographic Extent of Study	Summary or Conclusions	Missing Information or Data Gaps	Relevance to Study
	Taylor and Brabb, 1972 "Maps showing distribution and cost by counties of structurally damaging landslides in the SF Bay Region, winter of 1968-69." USGS Map MF-327	San Francisco Bay Region	Provides small scale maps showing the location of damaging landslides in San Francisquito Creek Watershed	Lacks volumes of landslides, volumes moved to streams, causes of slides. Incomplete as it only shows reported damaging landslides	Shows landslides active during the winter of 1968-69
	Taylor et al, 1975, "Distribution and costs of landslides that have damaged manmade structures during the rainy season of 1972-73 in the SF Bay Region." USGS Map MF-679	San Francisco Bay Region	Provides small scale maps showing the location of damaging landslides in San Francisquito Creek Watershed	Lacks volumes of landslides, volumes moved to streams, causes of slides. Incomplete as it only shows reported damaging landslides	Shows landslides active during the winter of 1972-73
	Creasey, 1988, "Landslide damage: costly outcome of the storm" in Ellen and Weiczorek (eds). USGS PP 1434	San Francisco Bay Region	Provides small scale maps showing the location of damaging landslides and debris flows in San Francisquito Creek Watershed	Lacks volumes of landslides, volumes moved to streams, causes of slides. Incomplete as it only shows reported damaging landslides	Shows landslides active during the winter of 1982-83
	Jayko et al, 1999, "Maps showing locations of damaging landslides in San Mateo County, CA, resulting from 1997-98 El Nino Rainstorms." USGS Map MF-2325-H.	San Francisco Bay Region	Provides maps showing the location of damaging landslides and flows in San Francisquito Creek Watershed and a data base describing each landslide	Provides some volumes, lacks volumes moved to streams. Incomplete as it only shows reported damaging landslides	Shows landslides active during the winter of 1997-98
	Wieczorek *et al*, 1988. "Debris flows and other landslides in San Mateo, Santa Cruz, Contra Costa, Alameda, Napa, Solano, Lake and Yolo Counties, and factors influencing debris flow distribution in Ellen and Weiczorek (eds) USGS PP 1434,	San Francisco Bay Region	Provides small scale maps of debris flow initiation points and track lengths in San Francisquito Creek watershed and a description of factors affecting their distribution	Typical dimensions provided but no debris flow volumes or volumes entering streams	Best debris flow inventory for San Francisquito Creek

	Studies or Data Bases	Geographic Extent of Study	Summary or Conclusions	Missing Information or Data Gaps	Relevance to Study
	Caroline Frey, 2001. "Geomorphic study of Searsville Lake watershed, Portola Valley, California" M.Sc, San Jose State University	Searsville Lake Watershed	GIS-based geomorphic mapping of large and small landslides that enter tributaries to Searsville Lake; mostly from 1997-98 El Nino storms	Areas of small slides provided but volumes of slides not calculated	Best digital record of small failures along streams
	Youd and Hoose, 1978, "Historic ground failures in northern California triggered by earthquakes" USGS PP 993	San Francisco Bay Region	Provides maps and descriptions of historic failures, emphasizing the 1906 earthquake	Volumes not included; those landslides in remote areas not inventoried or described; incomplete record.	General background on potential slope failures during earthquake
	Manson *et al*, 1992. "Landslides and other geologic features in the Santa Cruz Mountains, California resulting from the Loma Prieta earthquake of October 17, 1989" CDMG OFR 91-05	Santa Cruz Mountains	Maps of landslides and other features resulting from 1989 Loma Prieta earthquake	Volumes to streams not provided	No landslides identified in SF Creek Watershed
	Keefer (ed), 1998, "The Loma Prieta, California, earthquake of October 17, 1989 – Landslides" USGS PP 1551-C	Santa Cruz Mountains	Detailed analysis of landslides and other features resulting from Loma Prieta earthquake	Volumes to streams not provided	No landslides identified in SF Creek Watershed
Landslide and Debris Flow Susceptibility	Nilsen *et al*, 1976. "Natural conditions that control landsliding in the San Francisco Bay region – an analysis based on data from the 1968-69 and 1972-73 rain seasons" USGS Bulletin 1424	San Francisco Bay Region	Identifies primary factors causing landslides in San Francisco Bay region	General background information; updated by Pike *et al* 2001.	Background information
	Mark, R. 1992. "Maps of debris-flow probability, San Mateo County, California" USGS MI Map I-1257-M.	San Mateo County	Delineation of probable debris flow sites in San Mateo County	San Mateo County only; updated by Ellen et al 1997	Background information
	Weiczorek et al. 1985. "Map showing slope stability during earthquakes in San Mateo County, California" USGS MI Map I-1257-E	San Mateo County	Delineation of potential failures sites during earthquakes	San Mateo County only	Background information

	Studies or Data Bases	Geographic Extent of Study	Summary or Conclusions	Missing Information or Data Gaps	Relevance to Study
	Wentworth *et al*, 1997. "Summary distribution of slides and earthflows in San Mateo County" in "San Francisco Bay Region Landslide Folio" USGS OF97-745C	San Francisco Bay Region	Digital maps showing distribution of landslides and earthflows	From existing studies and databases and provides useful information on susceptibility by subwatershed	Useful in evaluating subwatershed
	Ellen *et al*, 1997. "Map showing principal debris-flow source areas in San Mateo County, California" in "San Francisco Bay Region Landslide Folio" USGS OFR 97-745E	San Francisco Bay Region	Digital maps showing areas calculated to be susceptible to debris flows from topographic data and showing the distribution of mapped 1982 debris flows.	Indicates physiographic parameters likely to affect distribution of debris flows	Provides digital data base of 1982 debris flow initiation points
	Pike *et al*, 2001. "Map and map database of susceptibility to slope failure by sliding and earthflow in the Oakland area, California"	Oakland, CA	Landslide susceptibility analysis based on geologic formation, slope, and the presence of past landslide deposits	Study limited to Oakland area. Indicates physiographic parameters likely to affect distribution of landslides	Background information
Other Sediment Sources	Brown and Jackson, 1973. "Erosional and depositional provinces and sediment transport in the south and central part of the San Francisco Bay Region, California" USGS MF-515	South and Central San Francisco Bay Region	Identifies and maps erosional and depositional provinces and identifies the dominant erosion processes in each province. Provides overview of geology, topography, soils, vegetation, land use, and erodibility;	Background information only	Background information on erosion processes for overview
	Balance Hydrologics, 1996. "Sedimentation and channel dynamics of the Searsville Lake watershed and Jasper Ridge Biological Preserve, San Mateo County, California"	Searsville Lake Watershed	Discussion of sediment sources, dynamics of sediment transport, and historical sedimentation rates in the Searsville Lake watershed	Surveys of Searsville Lake deposition updated in **nhc** et al 2002	Background on erodibility of geologic formations

	Studies or Data Bases	Geographic Extent of Study	Summary or Conclusions	Missing Information or Data Gaps	Relevance to Study
	Caroline Frey, 2001. "Geomorphic study of Searsville Lake watershed, Portola Valley, California" M.Sc Thesis, San Jose State University	Searsville Lake Watershed	GIS-based geomorphic mapping of erosional and depositional features along tributaries to Searsville Lake; classifies severity of bank erosion, deposition areas, and describes incision and other channel adjustments	Describes conditions following the 1997-98 El Nino storms. Lacks volumes of sediment from different processes	Best source of information on erosion processes along streams in SF Watershed
Geological Maps and Materials	Brabb and Pampeyan, 1983. "Geologic map of San Mateo County, California" USGS MF Map I-1257-A	San Mateo County (covers majority of San Francisquito Creek watershed)	geologic map; includes subdivision of quaternary deposits into genetic types	Updated by Brabb et al 2000	Nature and distribution of geologic materials
	U.S. Geological Survey, 1985. "Map of hillside materials and description of their engineering character, San Mateo County, California" I-1257D	San Mateo County (covers majority of San Francisquito Creek watershed)	Identifies geologic and geotechnical properties of hillslope materials, including permeability, expansivity, stability, underlying geology, and soil properties.	Limited to San Mateo County portion of watershed	Natural and distribution of surficial materials
	Helley *et al*, 1979. "Flatland deposits of the San Francisco Bay region, California - their geology and engineering properties and their importance to comprehensive planning" USGS PP-943	San Francisco Bay Region	Characterizes the origin and composition of alluvial fan and valley deposits; geologic maps of alluvial sediments are provided.	Describes geologic history of lower portion of watershed; limited relevance to sediment production	Background on geologic materials and their properties
	Brabb *et al*, 2000, Geologic map and map database of the Palo Alto 30' by 60' quadrangle, California" USGS Map MF-2332	Palo Alto area	Digital map and description of geologic formations in SF Creek watershed	Complete map for SF Creek. Provides nature of materials by subwatershed	Nature and distribution of geologic materials

	Studies or Data Bases	Geographic Extent of Study	Summary or Conclusions	Missing Information or Data Gaps	Relevance to Study
Channel Alignment and Materials	Royston, Hanamoto, Alley, & Abey, 2000. "San Francisquito Creek bank stabilization and revegetation, existing conditions report"	San Francisquito Creek from Junipero Serra Blvd to Hwy 101	Describes historic alignment and incision on San Francisquito Creek. Assesses current bank stability; provides detailed analysis and map of substrate	**nhc** *et al* 2002 reviews some of the same information	Provides some historic perspective on bank stability; detailed study of existing substrate
	Northwest Hydraulic Consultants and others, 2002. "Searsville Lake sediment impact study"	San Francisquito Creek	Describes historic alignment and incision on San Francisquito Creek. Calculates net volumes of deposition of incision from 1964 to 1998. Reviews changes in cross sections	No information on sediment sources, based on recent sediment supply from upper watershed	Provides volumes for a sediment budget along San Francisquito Creek
	Caroline Frey, 2001. "Geomorphic study of Searsville Lake watershed, Portola Valley, California"	Searsville Lake Watershed	Provides comments on changes in channel pattern and incision of tributaries	Change adjustments result from 1997-98 storms; no volumes or details on processes	Useful contribution to Searsville Lake sediment budget
	nhc and JSA, 1999, "Family Farm Road Flood and Sediment Control Study"	Corte Madera Creek near Searsville Lake	Examined historic changes in pattern of Corte Madera Creek and deposition on its fan at the head of Searsville Lake	**nhc** *et al* 2002 update the fan deposition; examines earliest and latest patterns	Useful history at head of Searsville Lake, updated later
	Allardt and Grunsky, 1888. "Investigations of San Francisquito Creek"	San Francisquito Creek	Historic surveys; discussed in RHAA and **nhc** *et al*	Survey results summarized by others	Historic perspective on channel adjustments
	Coyote Creek Riparian Station, 1994. "San Francisquito Creek survey summary 1993-94."	Stations on San Francisquito, Los Trancos, West Union, Bear and Corte Madera Creeks	Substrate pebble counts and profile surveys near stations	Limited to station locations and year surveyed	More recent information on SF creek
	Coyote Creek Riparian Station, 1998. "San Francisquito Creek upper watershed volunteer monitoring program (Nov 97 to Oct 98)."	Stations on San Francisquito, Los Trancos, West Union, Bear and Corte Madera Creeks	Substrate pebble counts and profile surveys near stations	Limited to station locations and year surveyed	More recent information on SF creek

	Studies or Data Bases	Geographic Extent of Study	Summary or Conclusions	Missing Information or Data Gaps	Relevance to Study
Flow and Sediment Measurements	Metzger, 2002. "Streamflow gains and losses along San Francisquito Creek and characterization of surface-water and ground-water quality, southern San Mateo and Northern Santa Clara Counties" USGS WRIR 02-4078	San Francisquito Creek	Describes surface water and ground water interactions and summarizes average stream losses and gains by reach for low flow period	None	Background information
	U.S. Geological Survey Gage "San Francisquito Creek at Stanford University (gage #11164500)"	San Francisquito Creek.	Streamflow records from 1932 - 41 and 1951 – present. Balance and **nhc** *et al* provide estimates of annual and peak flows for missing years	Data gaps filled by others	Background information on extreme floods helpful in evaluating sediment transport
	Brown and Jackson, 1973. "Erosional and depositional provinces and sediment transport in the south and central part of the San Francisco Bay Region, California" USGS MF-515	South and Central San Francisco Bay Region	Provides annual suspended sediment loads for 1962 to 1969 at the SF Creek gage	Background information only	Important measure of historic yields from Los Trancos and Bear Creeks.
	Crippen and Waananen, 1969, Hydrologic effects of suburban development near Palo Alto, CA USGS OFR	Three small tributaries to Bear, Los Trancos and SF Creek	Summarizes hydrologic and sediment transport changes from urban development in the early 1960s. Indicate construction impacts on loads	Measurements of sediment loads	Important component of historic sediment budget for San Francisquito Creek
	Balance Hydrologics, Inc, Various Dates and Annual Reports on Flow and Sediment Measurements. Stanford University.	Corte Madera Creek in Portola Valley	Annual flow, suspended and bedload at Corte Madera Creek at Westridge Road (1998 to 2001) and Los Trancos Creek at Arastradero Road (1995-2001)	Partly summarized in **nhc** *et al* 2002.	Important component of sediment budgets for Searsville Lake and Los Trancos
	Northwest Hydraulic Consultants and others, 2002. "Searsville Lake sediment impact study"	San Francisquito Creek Watershed	Provides long-term record of deposition in Searsville Lake, updating other studies. Measurements of sediment outflow from Searsville Lake and Bear Creek. Sediment transport model for lower San Francisquito Creek	No information on sediment sources, based on recent sediment supply from upper watershed	Important component of sediment budgets for Los Trancos, Bear and SF Creek subwatersheds

	Studies or Data Bases	Geographic Extent of Study	Summary or Conclusions	Missing Information or Data Gaps	Relevance to Study
Land Use	U.S. Geological Survey Topographic Maps (1899 - 1991)	San Mateo and Santa Clara Counties	Show roads and urban areas over time	Coverage not available for the entire watershed in all years. See Table 1 for details.	Basic source of historic land use
	U.S. Geological Survey Digital Orthophotos (1948, 1953, 1991)	San Francisco Bay Region	show development of roads and urban areas over time, orthorectified and easy to import into GIS	Air photos are limited to about 1940 and thereafter. See Table 1 for details	Basic source of historic land use
	San Mateo County Maps	San Mateo County	Road networks mapped for 1868, 1909, 1927, 1960 and 1973	Not complete coverage of SF Creek watershed; difficult to identify subwatershed boundaries on old maps	Basic source of historic road development
	Santa Clara Valley Water District, 2002.	South San Francisco Bay Region (includes 95 - 100% of San Francisquito Creek Watershed)	Infrared air photos in MrSid file format	Classification not completed	Useful for categorizing land use, bare soils, vegetation types
	Western Geoscience Center http://wgsc.wr.usgs.gov/sfcreek/	San Francisquito Creek Watershed	source of GIS data including DOQ's, DEM's, DLG's, land use, faults, landslides (general), and major roads and cities.	None	Digital data for land use
	Napier *et al*, 1992, Map showing land use and land cover in San Mateo County, California. USGS MI Map I-1257-L.	San Mateo County only	1:62,500-scale map of land use based on information from ABAG.	No digital data provided	Some historic interest
	EOA, Inc. 1998. "Impervious cover as a watershed management tool for San Mateo County watersheds"	San Francisquito Creek Watershed (and others in San Mateo County)	Total impervious area from percent impervious area cover by land use categories in San Francisquito Creek watershed	Only covers existing conditions; no breakdown to sub-watersheds or historic analysis	Useful for existing conditions for watershed health measure

	Studies or Data Bases	Geographic Extent of Study	Summary or Conclusions	Missing Information or Data Gaps	Relevance to Study
Vegetation	Royston, Hanamoto, Alley, & Abey, 2000. "San Francisquito Creek bank stabilization and revegetation, existing conditions report"	San Francisquito Creek from Junipero Serra Blvd to Hwy 101	conducted detailed mapping and identification of riparian vegetation along creek	study limited to downstream part of San Francisquito Creek	Medium, existing conditions only
	Northwest Hydraulic Consultants and others, 2002. "Searsville Lake sediment impact study"	San Francisquito Creek Watershed	Provides long-term record of deposition in Searsville Lake, updating other studies. Measurements of sediment outflow from Searsville Lake and Bear Creek. Sediment transport model for lower San Francisquito Creek	No information on sediment sources, based on recent sediment supply from upper watershed	Important component of sediment budgets for Los Trancos, Bear and SF Creek subwatersheds

Table B.1 Physical Characteristics of the San Francisquito Creek Subwatershed

Subwatershed	Sub-subwatershed	Area (acres)	Stream lengths (ft)	Average stream slope (%)	Minimum elevations (ft)	Maximum elevation (ft)	Watershed slope (%)	Length of Roads (miles)	Dominant Geologic Units
San Francisquito Creek	SF-1 to SF-12	8577	82160	5.5	0	2100	7.5	207	Qpaf, Tw, Qpoaf
	SF-1	1047	15450	1.6	0	125	1.7	30.3	Qhfp, Qhl, Qhb
	SF-2	1320	0	--	12	198	1.2	47.2	Qpaf, Qhb, Qhfp
	SF-3	833	11012	3.6	49	229	2.4	27.7	Qpaf, Qhl
	SF-4	648	3020	3.8	155	357	1.7	18.8	Qpaf, Qhl
	SF-5	372	1866	4.9	155	341	3.3	9.6	Qpaf, Qhl
	SF-6	243	0	--	198	695	5.4	8.2	Qpaf, QTsc
	SF-7	417	0	--	198	1481	10.9	10.4	QTsc, Tw, Qpaf
	SF-8	999	8597	8.1	198	1567	12.4	12.4	Tw, Qpoaf, Qpaf
	SF-9	496	2859	5.4	229	1109	5.9	12.3	Qpoaf, Qhl, QTsc
	SF-10	247	5976	5.9	360	1487	14.7	3.6	Qpoaf, Tlad, QTsc
	SF-11	1944	32170	7.8	482	2100	16.2	26.1	Tw, Tlad, Qpoaf
	SF-12	13	1210	9.5	771	1314	18.6	0.3	QTsc, fg, Qhaf

Table B.2 Physical Characteristics of the Corte Madera Creek Subwatershed

Subwatershed	Sub-subwatershed	Area (acres)	Stream lengths (ft)	Average stream slope (%)	Minimum elevations (ft)	Maximum elevation (ft)	Watershed slope (%)	Length of Roads (miles)	Dominant Geologic Units
Corte Madera Creek	CM-1 to CM-12	4366	62765	15.6	1070	7843	26.4	50.9	Tla, QTsc, Tw
	CM-1 Corte Madera Creek	811	8810	4.1	1070	2484	14.2	11.4	Tw, QTsc, Qpoaf
	CM-2 Corte Madera Creek	589	7459	7.8	1518	3417	15.9	11.5	Tw, QTsc, fg
	CM-3 Hamms Gulch	378	6976	21	2042	5880	31.5	1.4	Tp, Tb, Tst
	CM-4 Jones Gulch	361	5905	22.8	2042	6123	37.2	4.5	Tmb, Tla, Tst
	CM-5 Corte Madera Creek	251	3497	10.9	2027	6258	36.9	1.6	QTsc, Tp, Tla
	CM-6 Damiani Creek	283	3969	25.2	2405	6376	32.9	1.8	Tla, Tmb, Tst
	CM-7 Corte Madera Creek	337	5682	16.1	2399	5553	36.5	3.8	QTsc, Tp, Tst
	CM-8 Rengstorff Gulch	117	2808	24.1	3057	6721	35	1.2	Tla, Tls, Tmb
	CM-9 Coal Creek	237	3215	28.5	3078	7367	34.2	1.8	Tla, Tmb, Tls
	CM-10 Corte Madera Creek	86	1446	13.3	3078	6248	32.6	0.7	Tls, Tb, QTsc
	CM-11 unnamed stream	357	5745	15.9	3453	7766	25.4	4.4	Tla, Tmb, Tls
	CM-12 Corte Madera Creek	560	7253	14.8	3386	7843	25	6.8	Tla, Tls, QTsc

Table B.3 Physical Characteristics of the Los Trancos Creek Subwatershed

Subwatershed	Sub-subwatershed	Area (acres)	Stream lengths (ft)	Average stream slope (%)	Minimum elevations (ft)	Maximum elevation (ft)	Watershed slope (%)	Length of Roads (miles)	Dominant Geologic Units
Los Trancos Creek	LT-1 to LT-7	4870	87229	11.6	485	7166	23.4	50.7	fg, QTsc, Tw
	LT-1	405	8771	8.2	485	1622	12.7	4.5	Tlad, Qpoaf, QTsc
	LT-2	555	13049	7.1	600	2292	12.5	3.6	QTsc, fg, Tw
	LT-3	534	16010	5.8	536	2402	15.4	7.8	Tw, Qpoaf
	LT-4	649	10225	8.6	1091	2694	19.8	9.4	fg, Tw, Qpoaf
	LT-5	920	15138	18	1539	5322	31.4	9.4	fg, fsr, Qpaf
	LT-6	1000	14723	11.6	1554	5130	28.1	10.0	fg, Qtsc, fsr
	LT-7	807	9313	23.7	2777	7166	29.7	5.9	fg, fsr, QTsc

Table B.4 Physical Characteristics of the Alambique, Martin, Sausal, and Westridge Creek Subwatersheds

Subwatershed	Sub-subwatershed	Area (acres)	Stream lengths (ft)	Average stream slope (%)	Minimum elevations (ft)	Maximum elevation (ft)	Watershed slope (%)	Length of Roads (miles)	Dominant Geologic Units
Alambique Creek	AC-1 Alambique Creek	1492	13524	19	1067	6980	28.4	18.8	Tw, Tla, Qpoaf
Martin Creek	MC-1 Martin Creek	790	8420	19	1079	5502	27.4	11.8	Tw, Tb, Tla
Sausal Creek	SC-1 to SC-6	1547	30225	13.5	1067	5767	23.5	20.4	Tw, Tb, Tp
	SC-1 Sausal Creek	381	4798	4.6	1067	3456	18.3	6.3	Tw, Qpoaf, QTsc
	SC-2 Bull Run	409	8151	20.8	1268	5651	28.7	6.6	Tb, Tm
	SC-3 Sausal Creek	138	3414	2.5	1237	2493	13.6	3.1	Qpoaf, Tw, Tm
	SC-4 Neils Gulck	231	5938	19.7	1378	5767	29.3	1.6	Tp, Tb, Tm
	SC-5 Bozzo Gulch / Sausal Ck	280	5864	12.3	1375	5352	24.6	1.6	Tp, Qpoaf, Tb
	SC-6 Sausal Creek	107	2060	8.5	1631	3399	19.7	1.3	QTsc, Tw, Qpoaf
Westridge Creek	SL 1 and SL 2	1078	14131	12.0	847	2365	17.2	11.5	fg, Tw, QTsc
	SL-1 Westridge Creek	523	3082	15.2	847	2033	15	6.1	QTsc, fg, Qhb
	SL-2 Westridge Creek	556	11049	11.1	1070	2365	19.2	5.3	Tw, fg

Table B.5 Physical Characteristics of the Bear Creek, Bear Gulch, and West Union Creek Subwatersheds

Subwatershed	**Sub-subwatershed**	**Area (acres)**	**Stream lengths (ft)**	**Average stream slope (%)**	**Minimum elevations (ft)**	**Maximum elevation (ft)**	**Watershed slope (%)**	**Length of Roads (miles)**	**Dominant Geologic Units**
Bear Creek	BC-1 and BC-2	1582	24652	5.0	771	2743	11.9	28.3	QTsc, Tw, fg
	BC-1 Bear Creek	618	5537	4.8	771	1561	7.9	9.4	QTsc, Tw, Qpoaf
	BC-2 Bear Creek	964	19115	5	954	2743	14.4	18.9	QTsc, fg, Qcl
Bear Gulch	BG-1 to BG-3	2250	38643	14.8	3895	7333	28.9	16.3	Tw, Tla, QTsc
	BG-1 Bear Gulch	428	8838	4.6	954	1649	7.8	6.4	QTsc, Tw
	BG-2 Bear Gulch	1239	17713	15.4	1155	6928	32.3	6.5	Tw, Tla
	BG-3 Bear Gulch	583	12092	21.4	3895	7333	37.2	3.4	Tla, Tw
West Union Creek	WUC-1 to WUC-11	3575	73248	17.1	1155	7294	27.8	25.0	Tw
	WUC-1 West Union Creek	170	1558	1.9	1155	4334	23.8	2.4	Tw, Qpoaf
	WUC-2 Appletree Gulch	242	6556	20.7	1180	5505	32.4	1.1	Tw, Qpoaf
	WUC-3 West Union Creek	139	2215	5	1183	4285	18.4	1.7	Qpoaf, Tw, QTsc
	WUC-4 Tripp Gulch	271	7313	21.7	1274	6133	29.8	0.9	Tw
	WUC-5 West Union Creek	192	3179	9	1268	3444	20.1	2.3	Tw, QTsc, Qpoaf
	WUC-6 Squealer Gulch	528	12872	18.7	1445	7294	31.1	5.8	Tw
	WUC-7 West Union Creek	281	3895	10.6	1451	3999	19.9	4.3	Tw, QTsc
	WUC-8 McGarvey Gulch	543	9343	19.3	1878	6367	27.5	4.5	Tw
	WUC-9 Unnamed Stream	272	7468	17.3	1902	6227	29.3	0.7	Tw
	WUC-10 West Union Creek	64	2068	6.1	1878	2761	21.3	0.1	Tw, QTsc, Qhaf
	WUC-11 West Union Creek	875	16781	18.6	1896	6392	30.6	1.1	Tw

Table C.1 Erosion Characteristics of the Bear Creek, Bear Gulch, and West Union Creek Subwatersheds

Subwatershed	**Sub-subwatershed**	**Area (acres)**	**Average Basin Slope (%)**	**% streams with high sediment production**[1]	**% streams with severe bank erosion**[2]	**# of landslides (big/small)**[3]	**% stream length near landslide zone**[4]	**# of debris flows**[5]	**% area with erosive geology**[6]	**% stream length with erosive slopes**[7]
Bear Creek	BC-1 and BC-2	1582	11.9	--	--	--	0	1	73	0%
	BC-1 Bear Creek	618	7.9	--	--	--	0	0	88	0%
	BC-2 Bear Creek	964	14.4	--	--	--	0	1	64	0%
Bear Gulch	BG-1 to BG-3	2250	28.9	--	--	--	21	7	94	31%
	BG-1 Bear Gulch	428	7.8	--	--	--	0	0	90	0%
	BG-2 Bear Gulch	1239	32.3	--	--	--	39	2	92	30%
	BG-3 Bear Gulch	583	37.2	--	--	--	0	5	100	55%
West Union Creek	WUC-1 to WUC-11	3575	27.8	--	--	--	7	19	93	35%
	WUC-1 West Union Creek	170	23.8	--	--	--	0	0	58	0%
	WUC-2 Appletree Gulch	242	32.4	--	--	--	27	0	88	47%
	WUC-3 West Union Creek	139	18.4	--	--	--	0	0	59	0%
	WUC-4 Tripp Gulch	271	29.8	--	--	--	41	0	91	53%
	WUC-5 West Union Creek	192	20.1	--	--	--	0	0	79	13%
	WUC-6 Squealer Gulch	528	31.1	--	--	--	0	1	98	38%
	WUC-7 West Union Creek	281	19.9	--	--	--	0	6	91	4%
	WUC-8 McGarvey Gulch	543	27.5	--	--	--	0	7	100	44%
	WUC-9 Unnamed Stream	272	29.3	--	--	--	0	0	100	28%
	WUC-10 West Union Creek	64	21.3	--	--	--	0	1	88	1%
	WUC-11 West Union Creek	875	30.6	--	--	--	7	4	100	42%

1 = from Frey (2001) - calculated by dividing streams with classes 1 and 2 by total stream length
2 = from Frey (2001) - calculated by dividing streams with severely eroding banks by total stream length
3 = from Frey (2001) - refers to number of landslides bordering the creek channel
4 = from USGS (Wentworth et al., 1997)
5 = from USGS (Wentworth et al., 1997)
6 = Erosive geologies determined from Frey (2001), Wieczorek et al. (1989), and Balance Hydrologics (1996) and consist of Purisima Formation (Tp), Santa Clara Formation (Qtsc), Vaqueros Formation (Tvq), San Lorenzo Formation and Lambert Shale (Tls, Tst, Tla, Tmb), Whiskey Hill Formation (Tw, Tws), Monterey Formation (Tm),
7 = slopes ranging from 360m/km to 580m/km were found to contain the highest percentage of high sediment producting streams by Frey (2001)

Table C.2 Erosion Characteristics of the Corte Madera Creek Subwatershed

Subwatershed	**Sub-subwatershed**	**Area (acres)**	**Average Basin Slope (%)**	**% streams with high sediment production**[1]	**% streams with severe bank erosion**[2]	**# of landslides (small/large)**[3]	**% stream length near landslide zone**[4]	**# of debris flows**[5]	**% area with erosive geology**[6]	**% stream length with erosive slopes**[7]
Corte Madera Creek	CM-1 to CM-12	4366	26	38	50.1	335 / 21	56	14	85	30%
	CM-1 Corte Madera Creek	811	14.2	6.3	39.8	8 / 0	0	0	68	1%
	CM-2 Corte Madera Creek	589	15.9	10.4	38.6	8 / 1	19	0	67	2%
	CM-3 Hamms Gulch	378	31.5	46.9	44.7	38 / 0	49	6	81	52%
	CM-4 Jones Gulch	361	37.2	33.5	43.4	30 / 0	42	2	94	55%
	CM-5 Corte Madera Creek	251	36.9	33.6	47.9	28 / 1	24	1	100	6%
	CM-6 Damiani Creek	283	32.9	56.4	58.8	51 / 0	81	2	100	70%
	CM-7 Corte Madera Creek	337	36.5	30.6	37.4	24 / 7	100	2	97	28%
	CM-8 Rengstorff Gulch	117	35	--	--	--	100	0	96	74%
	CM-9 Coal Creek	237	34.2	36.9	42.1	18 / 0	100	0	97	73%
	CM-10 Corte Madera Creek	86	32.6	27.5	55.9	4 / 0	100	0	69	8%
	CM-11 unnamed stream	357	25.4	78.8	63.3	45 / 1	100	1	95	23%
	CM-12 Corte Madera Creek	560	25	88.4	93.4	81 / 11	100	0	90	16%

1 = from Frey (2001) - calculated by dividing streams with classes 1 and 2 by total stream length
2 = from Frey (2001) - calculated by dividing streams with severely eroding banks by total stream length
3 = from Frey (2001) - refers to number of landslides bordering the creek channel
4 = from USGS (Wentworth et al., 1997)
5 = from USGS (Wentworth et al., 1997)
6 = Erosive geologies determined from Frey (2001), Wieczorek et al. (1989), and Balance Hydrologics (1996) and consist of Purisima Formation (Tp), Santa Clara Formation (Qtsc), Vaqueros Formation (Tvq), San Lorenzo Formation and Lambert Shale (Tls, Tst, Tla, Tmb), Whiskey Hill Formation (Tw, Tws), Monterey Formation (Tm),
7 = slopes ranging from 360m/km to 580m/km were found to contain the highest percentage of high sediment producting streams by Frey (2001)

Table C.3 Erosion Characteristics of the Los Trancos Creek Subwatershed

Subwatershed	**Sub-subwatershed**	**Area (acres)**	**Average Basin Slope (%)**	**% streams with high sediment production**[1]	**% streams with severe bank erosion**[2]	**# of landslides (small/large)**[3]	**% stream length near landslide zone**[4]	**# of debris flows**[5]	**% area with erosive geology**[6]	**% stream length with erosive slopes**[7]
Los Trancos Creek	LT-1 to LT-7	4870	23.4	--	--	--	21.5	11	36	18%
	LT-1	405	12.7	--	--	--	0	0	70	2%
	LT-2	555	12.5	--	--	--	0	0	67	1%
	LT-3	534	15.4	--	--	--	0	0	60	3%
	LT-4	649	19.8	--	--	--	0	0	42	8%
	LT-5	920	31.4	--	--	--	16	1	0	33%
	LT-6	1000	28.1	--	--	--	35	1	31	16%
	LT-7	807	29.7	--	--	--	68	9	25	70%

1 = from Frey (2001) - calculated by dividing streams with classes 1 and 2 by total stream length
2 = from Frey (2001) - calculated by dividing streams with severely eroding banks by total stream length
3 = from Frey (2001) - refers to number of landslides bordering the creek channel
4 = from USGS (Wentworth et al., 1997)
5 = from USGS (Wentworth et al., 1997)
6 = Erosive geologies determined from Frey (2001), Wieczorek et al. (1989), and Balance Hydrologics (1996) and consist of Purisima Formation (Tp), Santa Clara Formation (Qtsc), Vaqueros Formation (Tvq), San Lorenzo Formation and Lambert Shale (Tls, Tst, Tla, Tmb), Whiskey Hill Formation (Tw, Tws), Monterey Formation (Tm),
7 = slopes ranging from 360m/km to 580m/km were found to contain the highest percentage of high sediment producting streams by Frey (2001)

Table C.4 Erosion Characteristics of the Alambique, Martin, Sausal, and Westridge Creek Subwatersheds

Subwatershed	Sub-subwatershed	Area (acres)	Average Basin Slope (%)	% streams with high sediment production[1]	% streams with severe bank erosion[2]	# of landslides (small/large)[3]	% stream length near landslide zone[4]	# of debris flows[5]	% area with erosive geology[6]	% stream length with erosive slopes[7]
Alambique Creek	AC-1 Alambique Creek	1492	28.4	18.7	23.2	47 / 0	32	18	86	39%
Martin Creek	MC-1 Martin Creek	790	27.4	11.1	18.7	25 / 3	91	16	56	51%
Sausal Creek	SC-1 to SC-6	1547	23.5	12.1	13.7	48 / 6	37	6	65	28%
	SC-1 Sausal Creek	381	18.3	0	7.0	0 / 0	0	0	77	2%
	SC-2 Bull Run	409	28.7	31.2	18.2	34 / 6	53	2	50	51%
	SC-3 Sausal Creek	138	13.6	0	4.8	0 / 0	0	0	57	0%
	SC-4 Neils Gulch	231	29.3	14.9	24.5	12 / 0	86	2	63	50%
	SC-5 Bozzo Gulch / Sausal Ck	280	24.6	3.4	10.6	2 / 0	52	2	68	18%
	SC-6 Sausal Creek	107	19.7	0	3.4	0 / 0	12	0	84	0%
Westridge Creek	SL 1 and SL 2	1078	17.2	0	0	1 / 0	4	0	38	13%
	SL-1 Westridge Creek	523	15	0	0	1 / 0	0	0	30	19%
	SL-2 Westridge Creek	556	19.2	0	0	0 / 0	7	0	46	11%

1 = from Frey (2001) - calculated by dividing streams with classes 1 and 2 by total stream length
2 = from Frey (2001) - calculated by dividing streams with severely eroding banks by total stream length
3 = from Frey (2001) - refers to number of landslides bordering the creek channel
4 = from USGS (Wentworth et al., 1997)
5 = from USGS (Wentworth et al., 1997)
6 = Erosive geologies determined from Frey (2001), Wieczorek et al. (1989), and Balance Hydrologics (1996) and consist of Purisima Formation (Tp), Santa Clara Formation (Qtsc), Vaqueros Formation (Tvq), San Lorenzo Formation and Lambert Shale (Tls, Tst, Tla, Tmb), Whiskey Hill Formation (Tw, Tws), Monterey Formation (Tm),
7 = slopes ranging from 360m/km to 580m/km were found to contain the highest percentage of high sediment producting streams by Frey (2001)

Table C.5 Erosion Characteristics of the San Francisquito Creek Subwatershed

Subwatershed	**Sub-subwatershed**	**Area (acres)**	**Average Basin Slope (%)**	**% streams with high sediment production**[1]	**% streams with severe bank erosion**[2]	**# of landslides (small/large)**[3]	**% stream length near landslide zone**[4]	**# of debris flows**[5]	**% area with erosive geology**[6]	**% stream length with erosive slopes**[7]
San Francisquito Creek	SF-1 to SF-12	8577	7.5	--	--	--	2.5	0	27	4%
	SF-1	1047	1.7	--	--	--	0	0	0	0%
	SF-2	1320	1.2	--	--	--	0	0	0	0%
	SF-3	833	2.4	--	--	--	0	0	0	0%
	SF-4	648	1.7	--	--	--	0	0	0	0%
	SF-5	372	3.3	--	--	--	0	0	0	0%
	SF-6	243	5.4	--	--	--	0	0	26	0%
	SF-7	417	10.9	--	--	--	0	0	74	0%
	SF-8	999	12.4	--	--	--	0	0	44	3%
	SF-9	496	5.9	--	--	--	0	0	26	0%
	SF-10	247	14.7	--	--	--	0	0	42	2%
	SF-11	1944	16.2	--	--	--	11	0	65	9%
	SF-12	13	18.6	--	--	--	0	0	48	13%

1 = from Frey (2001) - calculated by dividing streams with classes 1 and 2 by total stream length
2 = from Frey (2001) - calculated by dividing streams with severely eroding banks by total stream length
3 = from Frey (2001) - refers to number of landslides bordering the creek channel
4 = from USGS (Wentworth et al., 1997)
5 = from USGS (Wentworth et al., 1997)
6 = Erosive geologies determined from Frey (2001), Wieczorek et al. (1989), and Balance Hydrologics (1996) and consist of Purisima Formation (Tp), Santa Clara Formation (Qtsc), Vaqueros Formation (Tvq), San Lorenzo Formation and Lambert Shale (Tls, Tst, Tla, Tmb), Whiskey Hill Formation (Tw, Tws), Monterey Formation (Tm),
7 = slopes ranging from 360m/km to 580m/km were found to contain the highest percentage of high sediment producting streams by Frey (2001)

Table D.1 Historic Road Characteristics of the San Francisquito Creek Subwatershed[1]

Subwatershed	Sub-subwatershed	Area (acres)	1868-99			1953-55			1968		
			Paved Roads (miles)	Unpaved Roads (miles)	# of bridge crossings	Paved Roads (miles)	Unpaved Roads (miles)	# of bridge crossings	Paved Roads (miles)	Unpaved Roads (miles)	# of bridge crossings
San Francisquito Creek	SF-1 to SF-12	8577	--	56.6	6	149.2	9.1	24	191.6	13.9	24
	SF-1	1047	--	4.3	--	25.1	1.2	3	29.2	1.1	3
	SF-2	1320	--	17.4	1	43.9	0.1	0	47.1	--	0
	SF-3	833	--	12.2	2	26.7	0.4	1	27.6	0.1	1
	SF-4	648	--	3.8	--	17.6	0.3	0	18.6	0.2	0
	SF-5	372	--	4.2	--	4.9	1.3	0	9.5	--	0
	SF-6	243	--	2.4	--	8.0	0.8	0	8.1	--	0
	SF-7	417	--	2.7	--	5.0	0.4	0	10.2	--	0
	SF-8	999	--	4.5	--	5.0	1.6	2	8.4	3.0	2
	SF-9	496	--	1.4	1	9.0	--	1	12.3	--	1
	SF-10	247	--	0.9	1	1.6	0.3	1	3.0	0.7	1
	SF-11	1944	--	2.8	1	2.4	2.5	15	17.6	8.5	15
	SF-12	13	--	--	--	--	0.2	1	--	0.3	1

1 - All road lengths were measured from historic maps and are considered accurate to within +/-15%

Table D.2 Historic Road Characteristics of the Corte Madera Creek Subwatershed[1]

Subwatershed	Sub-subwatershed		Area (acres)	1868-99			1953-55			1968		
				Paved Roads (miles)	Unpaved Roads (miles)	# of bridge crossings	Paved Roads (miles)	Unpaved Roads (miles)	# of bridge crossings	Paved Roads (miles)	Unpaved Roads (miles)	# of bridge crossings
Corte Madera Creek	CM-1 to CM-12		4366	--	16.9	--	16.2	10.2	13	28.3	13.8	13
	CM-1	Corte Madera Creek	811	--	1.0	--	1.5	1.1	2	10.2	1.0	2
	CM-2	Corte Madera Creek	589	--	2.7	--	5.0	0.9	3	6.2	1.5	3
	CM-3	Hamms Gulch	378	--	0.3	--	--	0.7	0	--	1.4	0
	CM-4	Jones Gulch	361	--	2.5	--	2.7	0.7	3	2.7	1.8	3
	CM-5	Corte Madera Creek	251	--	0.8	--	0.9	0.8	2	0.9	0.6	2
	CM-6	Damiani Creek	283	--	0.8	--	0.6	--	1	0.6	0.8	1
	CM-7	Corte Madera Creek	337	--	1.9	--	1.8	1.9	1	1.7	1.6	1
	CM-8	Rengstorff Gulch	117	--	0.6	--	0.5	--	0	0.5	--	0
	CM-9	Coal Creek	237	--	0.9	--	0.8	0.1	0	1.0	0.1	0
	CM-10	Corte Madera Creek	86	--	0.4	--	0.1	0.3	0	0.3	0.2	0
	CM-11	unnamed stream	357	--	1.6	--	1.1	0.4	0	1.3	0.7	0
	CM-12	Corte Madera Creek	560	--	3.4	--	1.2	3.3	1	2.9	4.1	1

1 - All road lengths were measured from historic maps and are considered accurate to within +/-15%

Table D.3 Historic Road Characteristics of the Los Trancos Creek Subwatershed[1]

Subwatershed	Sub-subwatershed	Area (acres)	1868-99			1953-55			1968		
			Paved Roads (miles)	Unpaved Roads (miles)	# of bridge crossings	Paved Roads (miles)	Unpaved Roads (miles)	# of bridge crossings	Paved Roads (miles)	Unpaved Roads (miles)	# of bridge crossings
Los Trancos Creek	LT-1 to LT-7	4870	--	10.8	3	16.9	8.3	26	31	15.4	26
	LT-1	405	--	0.5	--	0.9	--	0	3.7	1.0	0
	LT-2	555	--	0.5	--	0.8	0.5	5	2.7	1.0	5
	LT-3	534	--	2.0	1	4.9	0.8	7	6.7	1.2	7
	LT-4	649	--	1.6	1	3.7	1.4	5	7.2	1.4	5
	LT-5	920	--	2.0	--	1.5	2.2	5	3.7	4.2	5
	LT-6	1000	--	2.5	1	3.5	2.3	2	4.2	3.7	2
	LT-7	807	--	1.7	--	1.6	1.1	2	2.8	2.9	2

1 - All road lengths were measured from historic maps and are considered accurate to within +/-15%

Table D.4 Historic Road Characteristics of the Alambique, Martin, Sausal, and Westridge Creek Subwatersheds[1]

Subwatershed	**Sub-subwatershed**	**Area (acres)**	**1868-99**			**1953-55**			**1968**		
			Paved Roads (miles)	Unpaved Roads (miles)	# of bridge crossings	Paved Roads (miles)	Unpaved Roads (miles)	# of bridge crossings	Paved Roads (miles)	Unpaved Roads (miles)	# of bridge crossings
Alambique Creek	AC-1 Alambique Creek	1492	--	5.7	--	5.1	11.3	4	7.2	12.1	4
			--								
Martin Creek	MC-1 Martin Creek	790	--	2.4	--	7.2	2.4	2	8.9	2.9	2
			--								
Sausal Creek	SC-1 to SC-6	1547	--	5.4	--	9.3	6.3	11	11.2	8.5	11
	SC-1 Sausal Creek	381	--	2.4	--	3.5	1.0	2	4.6	1.6	2
	SC-2 Bull Run	409	--	0.6	--	3.0	2.2	4	2.9	3.5	4
	SC-3 Sausal Creek	138	--	1.1	--	1.9	0.8	2	2.3	0.8	2
	SC-4 Neils Gulck	231	--	0.6	--	0.4	1.0	0	0.4	1.2	0
	SC-5 Bozzo Gulch / Sausal Ck	280	--	0.5	--	0.5	0.8	2	0.6	0.9	2
	SC-6 Sausal Creek	107	--	0.2	--	0.0	0.5	1	0.4	0.5	1
Westridge Creek	SL 1 and SL 2	1078	--	0.8	--	3.8	3.4	2	6.9	4.4	2
	SL-1 Westridge Creek	523	--	0.8	--	2.5	2.6	1	2.6	3.5	1
	SL-2 Westridge Creek	556	--	--	--	1.3	0.8	1	4.3	0.9	1

1 - All road lengths were measured from historic maps and are considered accurate to within +/-15%

Table D.5 Historic Road Characteristics of the Bear Creek, Bear Gulch, and West Union Creek Subwatersheds[1]

Subwatershed	**Sub-subwatershed**	**Area (acres)**	**1868-99**			**1953-55**			**1968**		
			Paved Roads (miles)	Unpaved Roads (miles)	# of bridge crossings	Paved Roads (miles)	Unpaved Roads (miles)	# of bridge crossings	Paved Roads (miles)	Unpaved Roads (miles)	# of bridge crossings
Bear Creek	BC-1 and BC-2	1582	--	6.3	--	20.4	1.1	10	25.8	2.3	10
	BC-1 Bear Creek	618	--	4.7	--	7.3	1.0	1	7.8	1.6	1
	BC-2 Bear Creek	964	--	1.6	--	13.1	0.1	9	18.0	0.7	9
Bear Gulch	BG-1 to BG-3	2250	--	4.3	1	8.6	6.9	7	8.8	7.4	7
	BG-1 Bear Gulch	428	--	1.6	--	5.2	0.1	6	5.9	0.5	6
	BG-2 Bear Gulch	1239	--	1.2	1	2.8	4.1	1	2.3	4.2	1
	BG-3 Bear Gulch	583	--	1.5	--	0.6	2.7	0	0.6	2.7	0
West Union Creek	WUC-1 to WUC-11	3575	--	13.7	1	10.8	9.6	24	15.3	10.1	24
	WUC-1 West Union Creek	170	--	0.6	--	1.3	0.1	1	1.7	0.7	1
	WUC-2 Appletree Gulch	242	--	0.6	--	0.4	0.0	4	1.0	0.1	4
	WUC-3 West Union Creek	139	--	1.0	--	1.1	0.0	0	1.7	0.0	0
	WUC-4 Tripp Gulch	271	--	0.7	--	0.5	0.0	4	0.9	0.0	4
	WUC-5 West Union Creek	192	--	1.0	--	1.4	0.0	0	2.1	0.2	0
	WUC-6 Squealer Gulch	528	--	0.7	1	3.4	2.2	11	4.3	2.0	11
	WUC-7 West Union Creek	281	--	1.5	--	1.4	2.4	2	2.1	2.2	2
	WUC-8 McGarvey Gulch	543	--	2.1	--	0.5	3.9	2	0.6	3.9	2
	WUC-9 Unnamed Stream	272	--	0.4	--	0.1	0.7	0	0.1	0.7	0
	WUC-10 West Union Creek	64	--	0.7	--	0.0	0.1	0	0.0	0.1	0
	WUC-11 West Union Creek	875	--	4.4	--	0.7	0.2	0	0.8	0.2	0

1 - All road lengths were measured from historic maps and are considered accurate to within +/-15%

Table E.1 Existing Road Characteristics of the San Francisquito Creek Subwatershed

Subwatershed	**Sub-subwatershed**	**Area (acres)**	**Length of roads (miles)**		**Length of roads within given slope class (miles)**						**Length of roads within erosive geologies (miles)**	
					0 - 20 degrees		**20 - 35 degrees**		**35+ degrees**			
			Paved	Unpaved	paved	unpaved	paved	unpaved	paved	unpaved	paved	unpaved
San Francisquito Creek	SF-1 to SF-12	8577	193.6	13.1	189.3	12.2	3.6	0.8	0.7	0.1	19.9	2.7
	SF-1	1047	29.2	1.1	29.2	1.1	--	--	--	--	--	--
	SF-2	1320	47.1	--	47.2	--	--	--	--	--	--	--
	SF-3	833	27.6	0.1	27.6	0.1	--	--	--	--	--	--
	SF-4	648	18.6	0.2	18.6	0.2	--	--	--	--	--	--
	SF-5	372	9.4	0.2	9.4	0.2	--	--	--	--	--	--
	SF-6	243	8.1	--	8.1	--	--	--	--	--	2.0	--
	SF-7	417	10.4	--	10.0	--	0.4	--	--	--	7.0	--
	SF-8	999	9.6	2.7	9.2	2.5	0.4	0.2	--	--	2.8	1.1
	SF-9	496	12.3	--	12.3	--	--	--	--	--	0.5	--
	SF-10	247	3.0	0.7	2.6	0.4	0.3	0.2	0.1	0.1	0.3	--
	SF-11	1944	18.3	7.8	15.2	7.4	2.5	0.4	0.6	--	7.3	1.4
	SF-12	13	--	0.3	--	0.2	--	0.1	--	--	--	0.1

Table E.2 Existing Road Characteristics of the Corte Madera Creek Subwatershed

Subwatershed	**Sub-subwatershed**	**Area (acres)**	**Length of roads (miles)**		**Length of roads within given slope class (miles)**						**Length of roads within erosive geologies (miles)**	
					0 - 20 degrees		**20 - 35 degrees**		**35+ degrees**			
			Paved	Unpaved	paved	unpaved	paved	unpaved	paved	unpaved	paved	unpaved
Corte Madera Creek	CM-1 to CM-12	4366	35.8	15.0	23.4	5.5	9.1	6.9	3.3	2.6	27.6	13.0
	CM-1 Corte Madera Creek	811	10.4	1.0	9.2	0.9	1.1	0.1	0.1	--	7.2	0.2
	CM-2 Corte Madera Creek	589	9.5	2.0	9.0	1.3	0.5	0.6	--	--	5.6	1.7
	CM-3 Hamms Gulch	378	0.0	1.4	--	0.6	--	0.6	--	0.2	1.0	--
	CM-4 Jones Gulch	361	2.7	1.8	0.6	0.3	1.1	0.9	1.0	0.7	2.5	1.8
	CM-5 Corte Madera Creek	251	0.9	0.6	0.4	0.2	0.4	0.3	0.1	0.2	0.9	0.6
	CM-6 Damiani Creek	283	0.9	0.8	0.3	0.2	0.6	0.5	0.1	0.1	0.9	0.8
	CM-7 Corte Madera Creek	337	2.2	1.7	0.8	0.6	1.1	0.5	0.3	0.6	2.0	1.7
	CM-8 Rengstorff Gulch	117	1.1	--	0.1	--	0.7	--	0.3	--	1.1	0.0
	CM-9 Coal Creek	237	1.8	0.1	0.6	--	0.5	--	0.7	--	1.8	0.1
	CM-10 Corte Madera Creek	86	0.5	0.2	0.2	--	0.2	0.2	0.1	--	0.3	0.2
	CM-11 unnamed stream	357	2.6	1.8	1.1	0.6	1.1	0.9	0.4	0.3	2.6	1.8
	CM-12 Corte Madera Creek	560	3.1	3.7	1.2	0.7	1.7	2.4	0.2	0.6	2.7	3.1

Table E.3 Existing Road Characteristics of the Los Trancos Creek Subwatershed

Subwatershed	**Sub-subwatershed**	**Area (acres)**	**Length of roads (miles)**		**Length of roads within given slope class (miles)**						**Length of roads within erosive geologies (miles)**	
					0 - 20 degrees		**20 - 35 degrees**		**35+ degrees**			
			Paved	Unpaved	paved	unpaved	paved	unpaved	paved	unpaved	paved	unpaved
Los Trancos Creek	LT-1 to LT-7	4870	35.9	14.8	26.0	9.5	9.2	3.9	0.7	1.4	14.0	3.2
	LT-1	405	3.7	0.8	3.5	0.8	0.1	--	--	--	0.9	--
	LT-2	555	2.7	1.0	2.3	0.9	0.3	0.1	0.1	--	0.8	0.6
	LT-3	534	6.7	1.2	5.7	1.1	1.0	0.1	--	--	3.3	0.6
	LT-4	649	8.0	1.4	6.2	1.2	1.7	0.1	0.2	--	4.5	0.1
	LT-5	920	5.1	4.3	3.0	2.4	2.0	1.5	0.2	0.5	--	--
	LT-6	1000	6.4	3.6	3.6	2.1	2.6	1.3	0.3	0.3	2.8	1.5
	LT-7	807	3.4	2.5	1.7	1.0	1.6	0.9	0.1	0.6	1.7	0.4

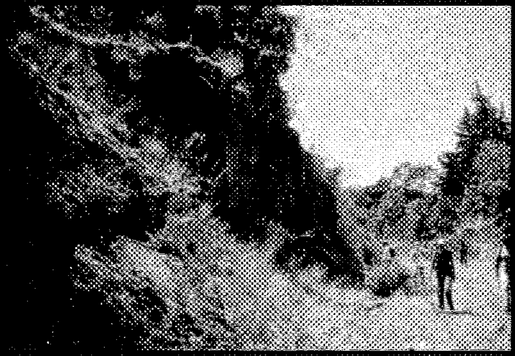
Table E.4 Existing Road Characteristics of the Alambique, Martin, Sausal, and Westridge Creek Subwatersheds

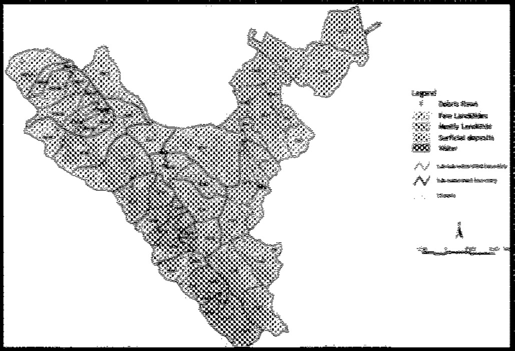
Subwatershed	**Sub-subwatershed**	**Area (acres)**	**Length of roads (miles)**		**Length of roads within given slope class (miles)**						**Length of roads within erosive geologies (miles)**	
					0 - 20 degrees		**20 - 35 degrees**		**35+ degrees**			
			Paved	Unpaved	paved	unpaved	paved	unpaved	paved	unpaved	paved	unpaved
Alambique Creek	AC-1 Alambique Creek	1492	7.2	11.6	4.5	2.9	2.2	4.9	0.5	3.8	5.4	11.0
Martin Creek	MC-1 Martin Creek	790	8.9	2.9	4.3	0.7	3.7	1.7	0.8	0.5	5.0	0.8
Sausal Creek	SC-1 to SC-6	1547	11.8	8.6	8.0	3.2	3.5	4.4	0.4	1.0	8.3	5.8
	SC-1 Sausal Creek	381	4.6	1.6	2.8	0.5	1.8	1.1	0.1	--	3.6	1.6
	SC-2 Bull Run	409	2.9	3.6	1.5	0.9	1.1	2.0	0.3	0.8	1.8	1.7
	SC-3 Sausal Creek	138	2.3	0.8	2.0	0.5	0.3	0.3	--	--	1.4	0.6
	SC-4 Neils Gulck	231	0.5	1.2	0.3	0.3	0.2	0.6	0.2	--	0.4	1.0
	SC-5 Bozzo Gulch / Sausal Ck	280	0.7	0.8	0.7	0.6	0.1	0.2	--	--	0.7	0.6
	SC-6 Sausal Creek	107	0.7	0.5	0.7	0.5	0.1	--	--	--	0.5	0.2
Westridge Creek	SL 1 and SL 2	1078	7.0	4.4	6.0	4.0	1.0	0.3	--	0.1	5.2	2.1
	SL-1 Westridge Creek	523	2.6	3.5	2.6	3.1	--	0.2	--	0.1	2.0	1.8
	SL-2 Westridge Creek	556	4.4	0.9	3.5	0.9	0.9	0.1	--	--	3.2	0.3

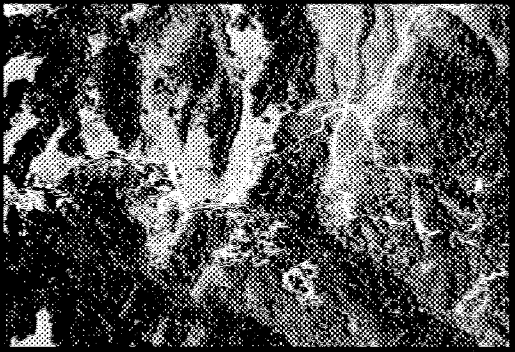
Table E.5 Existing Road Characteristics of the Bear Creek, Bear Gulch, and West Union Creek Subwatersheds

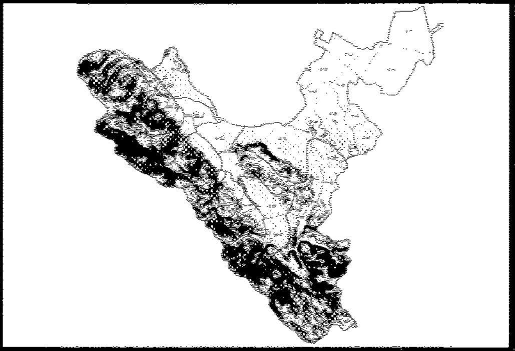
Subwatershed	**Sub-subwatershed**	**Area (acres)**	**Length of roads (miles)**		**Length of roads within given slope class (miles)**						**Length of roads within erosive geologies (miles)**	
					0 - 20 degrees		**20 - 35 degrees**		**35+ degrees**			
			Paved	Unpaved	paved	unpaved	paved	unpaved	paved	unpaved	paved	unpaved
Bear Creek	BC-1 and BC-2	1582	26.0	2.3	23.4	2.1	2.3	0.2	0.3	--	14.1	1.9
	BC-1 Bear Creek	618	7.8	1.6	7.8	1.6	--	--	--	--	5.8	1.3
	BC-2 Bear Creek	964	18.2	0.7	15.6	0.5	2.3	0.2	0.3	--	8.2	0.7
Bear Gulch	BG-1 to BG-3	2250	8.8	7.5	8.1	1.9	0.5	2.6	0.2	3.0	7.5	7.4
	BG-1 Bear Gulch	428	5.9	0.5	5.9	0.5	--	--	--	--	5.5	0.5
	BG-2 Bear Gulch	1239	2.3	4.2	1.9	0.9	0.3	2.1	--	1.3	1.3	4.2
	BG-3 Bear Gulch	583	0.6	2.8	0.3	0.5	0.2	0.5	0.2	1.7	0.6	2.8
West Union Creek	WUC-1 to WUC-11	3575	15.5	9.5	9.3	5.3	5.0	3.3	1.2	0.9	11.7	8.8
	WUC-1 West Union Creek	170	1.7	0.7	1.4	0.5	0.3	0.3	--	--	0.6	0.4
	WUC-2 Appletree Gulch	242	1.0	0.1	0.6	0.1	0.3	--	0.1	--	0.4	0.1
	WUC-3 West Union Creek	139	1.7	--	1.0	--	0.4	--	0.2	--	1.1	--
	WUC-4 Tripp Gulch	271	0.9	--	0.7	--	0.2	--	--	--	0.4	--
	WUC-5 West Union Creek	192	2.1	0.2	1.1	0.1	0.9	0.1	0.1	--	1.6	0.2
	WUC-6 Squealer Gulch	528	4.3	2.1	2.1	0.8	1.7	0.6	0.6	--	3.9	1.5
	WUC-7 West Union Creek	281	2.2	2.1	0.9	1.4	1.1	0.7	0.1	0.1	2.0	1.8
	WUC-8 McGarvey Gulch	543	0.6	3.9	0.5	1.7	0.1	1.4	--	0.8	0.6	3.8
	WUC-9 Unnamed Stream	272	0.1	0.7	0.1	0.6	--	0.1	--	--	0.1	0.7
	WUC-10 West Union Creek	64	--	0.1	--	0.1	--	--	--	--	--	0.1
	WUC-11 West Union Creek	875	0.8	0.2	0.8	0.1	--	0.1	--	--	0.8	0.2

Existing
Conditions
Analysis









July 2003

San Francisquito Creek Watershed Existing Conditions Analysis

DRAFT REPORT

Prepared for:

San Francisquito Creek
Joint Powers Authority

Prepared by:

nhc northwest hydraulic consultants
Leaders in water resource technology

Jones & Stokes

San Francisquito Creek
Watershed Analysis and Sediment Reduction Plan

Task 4.2
Existing Conditions Analysis

Draft Report
July 21, 2003

Prepared for:
San Francisquito Creek
Joint Powers Authority

Prepared by:
Northwest Hydraulic Consultants
3950 Industrial Boulevard, Suite 100c
West Sacramento, CA 95691
Contact: Ken Rood
(916) 371-7400

Jones & Stokes
2841 Junction Avenue, Suite 114
San Jose, CA 95134

TABLE OF CONTENTS

1. INTRODUCTION 1
   1.1 OBJECTIVES 1
   1.2 APPROACH 1
   1.3 SOURCES OF INFORMATION 1
2. SAN FRANCISQUITO WATERSHED 2
   2.1 PHYSIOGRAPHY AND GEOLOGY 2
   2.2 SURFACE WATER HYDROLOGY 2
   2.3 WATER MANAGEMENT STRUCTURES 4
   2.4 GROUNDWATER HYDROLOGY 5
   2.5 SEDIMENT TRANSPORT 6
3. WATERSHED CHARACTERISTICS 8
   3.1 BACKGROUND 8
   3.2 REACH DIVISION AND DESCRIPTION 8
4. LAND USE 11
   4.1 BACKGROUND 11
   4.2 EXISTING CONDITIONS 11
   4.3 HISTORICAL TRENDS 12
5. BIOLOGICAL RESOURCES 13
   5.1 BACKGROUND 13
   5.2 TERRESTRIAL HABITAT TYPES 13
   5.3 AQUATIC RESOURCES 15
   5.4 SPECIAL-STATUS SPECIES 17
6. RIPARIAN CORRIDOR MANAGEMENT POLICIES & PROGRAMS 19
   6.1 OVERVIEW 19
   6.2 LOCAL LAND USE AND DEVELOPMENT POLICIES 19
   6.3 STREAM MAINTENANCE AND MANAGEMENT 20
   6.4 NON-NATIVE SPECIES CONTROL 22
   6.5 DESIGNATED WATERSHED BENEFICIAL USES 22
7. REFERENCES 25

TABLES AND FIGURES

LIST OF TABLES

1. Stream Gages Operated on San Francisquito Creek and Tributaries
2. Large Water Management Structures on San Francisquito Creek and Associated Tributaries
3. Annual Transport Volumes and Denudation Rates in San Francisquito Watershed
4. Subwatershed and Sub-Subwatershed Acreages and Stream Lengths
5. Summary of Valley Segment and Reach Types in the Montgomery Buffington Method
6. Comparison of Results from Montgomery Buffington Method and Field Observations
7. Acreage of Existing Land Uses for the San Francisquito Watershed
8. Subwatershed Stream and Road Intersections Over Time
9. Projected Residential, Industrial and Commercial Development for the San Francisquito Watershed
10. Existing and Projected Percent Imperviousness for San Francisquito Watershed (1995)
11. Habitat Types within Subwatersheds
12. Occurrence of Fish in Collections from the San Francisquito Creek Drainage, 1855-1981
13. Historic and Current Freshwater Fish of the San Francisquito Watershed
14. Land Use Acreages within Riparian Corridors within the San Francisquito Watershed
15. Riparian Policies from Santa Clara and San Mateo County General Plans
16. Existing and Potential Beneficial Land Uses Within the San Francisquito Watershed

LIST OF FIGURES

1. Generalized Stream Classification from Montgomery and Buffington (1993)
2. Channel Types using the Montgomery-Buffington Classification
3. USGS 1899 Quadrangle
4. USGS 1948 DOQ
5. USGS 1993 DOQ
6. WHR GAP Vegetation
7. Road and Stream Intersections
8. California Natural Diversity Database

1. INTRODUCTION

1.1 Objectives

The objective of Task 4.2 is to describe the existing conditions of the San Francisquito Watershed including general characteristics, land uses, biological resources, stream management and maintenance and riparian corridor management policies and programs, and designated watershed beneficial uses.

1.2 Approach

The approach that was taken for this report included reviewing existing reports, maps, and other information for the San Francisquito watershed that are relevant to our objective of describing the existing conditions of the watershed.

The existing conditions analysis is an important precursor to the Task 5 Watershed Sediment Analysis and also to the Task 7 Sediment Reduction Plan. Because these two following tasks rely on different information, we have divided the existing conditions analysis into the following parts:

- A general description of the San Francisquito watershed;
- An overview of the watershed characteristics;
- A discussion of historic and existing lands uses, and trends over time;
- A review of historic and existing biological resources and habitats within the watershed;
- A description of stream management and maintenance programs and activities
- A summary of existing riparian corridor management policies and programs; and,
- Beneficial uses that have been designated within the watershed.

1.3 Sources of Information

A broad range of studies and information is available, describing the physical and biological characteristics of the San Francisquito Watershed. For the purposes of this study, the following sources of information were reviewed:

- Historic and current topo maps and air photos;
- Santa Clara Basin Watershed Management Initiative;
- California Department of Fish and Game Natural Diversity Database;
- U.S. Fish and Wildlife Service and U.C. Santa Barbara Gap Analysis Habitat Mapping; and,
- General studies that have been provided by the Technical Advisory Committee and the Palo Alto Regional Water Quality Control Plant.

2. SAN FRANCISQUITO WATERSHED

2.1 Physiography and Geology

The San Francisquito watershed is approximately 45 mi^2 in size. Most of the watershed lies in the Santa Cruz Mountains and Bay Foothills southwest of Palo Alto; the remaining 7.5 mi^2 of the watershed lies on the San Francisquito alluvial fan near San Francisco Bay. The San Andreas Fault Zone (SAFZ) is one of the most prominent features in the San Francisquito watershed, bisecting it in a northwest-southeast direction (Brabb *et al* 2000; Helley *et al* 1979). The steep, upper watershed lies southwest of the SAFZ in the northern Santa Cruz Mountains, while the more gradually sloping areas lie to the northeast. Unstable slopes and active landsliding are mostly found southwest of the SAFZ (Wentworth *et al* 1997).

The geologic formations in the upper San Francisquito watershed, southwest of the SAFZ, consist of Tertiary sedimentary rocks, primarily sandstones, mudstones and shales (Brabb *et al* 2000). The Franciscan Complex underlies the Bay foothills northeast of the SAFZ (Brabb *et al* 2000). Large areas of greenstone and graywacke, part of this Complex, underlie the southern part of the Los Trancos watershed.

The boundary or contact between the bedrock in the upper watershed and the unconsolidated materials around San Francisco Bay lies close to Alameda de Las Pulgas Road, along the Pulgas Fault ((Fio and Leighton 1994; Metzger 2002). The unconsolidated material is an alluvial apron, consisting of coalesced deposits from the tributaries draining to San Francisco Bay deposited during the Pleistocene and Holocene. It is thick near San Francisquito Creek (more than 1,000 feet) and includes lenses or layers of Bay Muds deposited during marine transgressions. San Francisquito Creek is incised into the alluvial apron deposits (Helley et al 1979).

Metzger (2002) prepared a geological profile along San Francisquito Creek downstream of Alameda de Las Pulgas Road based on well records. It shows a layer of coarse channel bed material (gravel, cobbles and boulders) extending downstream from Alameda de Las Pulgas Road as far downstream as Middlefield Road. This coarse material overlies a sandy deposit that continues under the streambed to the Palo Alto Municipal Golf Course. A thick layer of bay sediments with lenses of alluvium extends at depth beneath the sand upstream to about San Mateo Drive. These bay sediments are underlain at depth by older, more consolidated alluvium.

2.2 Surface Water Hydrology

STREAM GAGES

The "San Francisquito Creek at Stanford University (11164500)" gage, located on the Stanford Golf Course upstream of Junipero Serra Boulevard, provides the best long-term record of flow in San Francisquito Creek with measurements from 1931 to 1941 and then from 1951 to present. This gage has a watershed area of 37.5 mi^2 and measures the flow from the Santa Cruz Mountains and Bay Foothills.

The stream gages operated on San Francisquito Creek and its tributaries by the USGS are summarized in Table 1.

Balance Hydrologics, Inc currently operates stations on the tributaries to San Francisquito Creek for Stanford University. Data collection from these stations began in 1997 on Corte Madera Creek at Westridge Road and in 1995 on Los Trancos Creek at Arastradero Road (Owens, Chartrand and Hecht 2002).

Crippen and Waananen (1969) report measurements on three small tributaries in the Bay Foothills, from 1959 to 1965, showing the effect of suburban development on their hydrologic regime. Their study included the Los Trancos Creek Tributary described in Table 1. They identified increases in storm and annual runoff, a more rapid response to precipitation, an increase in the occurrence of frequent floods, and a change from ephemeral to perennial flow as a result of golf course irrigation resulting from conversion of rural lands.

ANNUAL FLOWS

San Francisquito Creek has a Mediterranean climate, with warm, dry summers and mild, wet winters. Average annual precipitation varies from 15 inches at Palo Alto (Metzger 2002) to about 40 inches in the upper watershed (Rantz 1971). The Corps of Engineers (1972) estimated an average annual precipitation over the watershed of about 32 inches. Average annual flow at the Stanford University gage is 21.4 cfs, equivalent to 7.7 inches of runoff, or about 25% of average annual precipitation.

nhc *et al* (2002) extended the record of annual flows to 1899 to 2000 water years at the Stanford gage, filling missing years in the recorded flow record through correlation with nearby long-term gages. Examination of this record shows distinct periods of high and low annual flows, with the periods of high flows spaced roughly 15 to 20 years apart. Streamflow has been particularly high from 1995 to 2000; other periods of consistent high flows include 1899 to 1911 and from 1937 to 1945.

PEAK FLOWS

The flood of record on San Francisquito Creek at the Stanford University gage occurred in 1998 with a peak of 7,200 cfs. Other notable floods – those exceeding 5,000 cfs based on reconstructed records – have occurred in 1894, 1895, 1911, 1955 and 1982 (Kittleson *et al* 1996; see also Corps of Engineers 1972).

The Corps of Engineers (1972) also notes that between 1910 and 1972 San Francisquito Creek overflowed its banks eight times – in 1911, 1916, 1919, 1940, 1943, 1950, 1955 and 1958. It also overflowed its banks in 1982 and then again in 1998 (Cushing 2000). Levees and channel modifications now contain the flows that overtopped the banks earlier in the twentieth century. As described by the Corps of Engineers (1972) and Cushing (2000) overflow now mostly occurs along the lower part of the creek, downstream of Middlefield Road, during extreme floods.

The tributaries to San Francisquito Creek in the upper watershed are all deeply incised and flooding had not been reported along them as of 1972 (Corps of Engineers 1972). Note that aggradation on the fan of Corte Madera Creek at the head of Searsville Lake has now resulted in flooding along Family Farm Road and its adjacent properties (see nhc and JSA 2000).

LOW FLOWS

Low flows at the Stanford University gage typically occur in the late summer or early fall, before winter rains begin. Downstream of this gage, the channel bed over the fan deposits is effluent and low flows infiltrate to groundwater, leaving much of the streambed dry for about six months of the year (Metzger 2002). Upstream of the gage, where San Francisquito Creek flows over bedrock, streamflow losses appear to be negligible.

Most of the streamflow losses or infiltration to groundwater occurs between San Mateo Drive and Middlefield Road where San Francisquito Creek crosses the Pulgas fault. Further downstream, losses are minimal and groundwater returns may supplement stream flows near Woodland Road. Storm drains also supplement natural flow at various sites along the reach and water chemistry measurements indicate that during moderate and low flows that streamflow downstream of San Mateo Drive is a mix of natural flows from the upper watershed and urban runoff (Metzger 2002).

Crippen and Waananen (1969) noted that the small tributaries in the Bay foothills and plains were ephemeral prior to development. Irrigation and watering following urbanization have resulted in perennial flows in some small tributaries to San Francisquito Creek, maintaining lows flows when previously there were none. However, most of the steep tributaries currently appear to have intermittent flows. The general nature of streamflow in the Santa Cruz Mountains is described in a later section.

2.3 Water Management Structures

The Corps of Engineers (1972) identified four major water management structures in the San Francisquito watershed (Table 2). These four reservoirs are thought to have only a minor effect on flood flows as their volumes are not very large compared to inflows, these reservoirs are often full when large floods occur, and flood flows are diverted around some reservoirs to avoid siltation (Corps 1972). There are also a number of small reservoirs and water diversion structures in the watershed that have not been inventoried.

During spring months, several acre-feet per day (roughly less than 10 cfs) are diverted from San Francisquito Creek, just upstream of the Stanford gage, to fill Lagunita Lake and maintain its water level. After commencement ceremonies, the lake is drained and water returned to San Francisquito Creek in mid-June (Metzger 2002).

Searsville Dam is no longer operated but, in the past, flashboards were installed in the spring to store about 4.5 feet of water for irrigation; these flashboards were removed in the fall to lower winter water levels in Searsville Lake. The operation of the other reservoirs is not known. However, it is likely that water utilization, evaporation, and diversion of flow to maintain summer reservoir levels has reduced spring, summer and fall flows to some extent in the San Francisquito watershed. Considerable further analysis would be required to evaluate the extent to which natural flows have been reduced.

2.4 Groundwater Hydrology

The aquifer that underlies the San Francisquito alluvial fan is an arbitrarily defined sub-basin of the larger aquifer that extends into the Santa Clara Valley (Sokol 1964; Fio and Leighton 1994). The sub-basin beneath the fan includes both a shallow aquifer in the sandy deposits that lie beneath San Francisquito Creek and a deeper one with water bearing strata at depths greater than 200 feet below the local ground surface.

The shallow aquifer extends to depths of up to 100 feet and lies above a layer of clayey bay deposits. This aquiclude or confining bed ends near San Mateo Drive. Upstream of this point, the shallow aquifer is apparently connected to the deeper one (Sokol 1964; Metzger 2002). Water levels in the shallow aquifer are below the stream bottom, particularly upstream of San Mateo Drive where they are more than 20 feet below the ground surface. Groundwater levels may be near the streambed just downstream of Middlefield Road and then again in the tidal reach, downstream of Highway 101 and through East Palo Alto.

As discussed earlier, stream flows from San Francisquito Creek infiltrate the streambed and recharge the aquifers. Metzger (2002) estimated annual losses of about 1,000 acre-feet, with most of the loss between San Mateo Drive and Middlefield Road. This is equivalent to about 9% of the long-term mean annual flow. Sokol (1964) estimated slightly smaller losses by comparing flows at the various gaging stations that operated on San Francisquito Creek in the 1930s (see Table 1). Seepage from Lake Lagunita, infiltration of runoff from the foothills, over-irrigation, and leakage from water distribution and stormwater systems also contribute to the aquifer recharge.

Metzger (2002), Metzger and Fio (1997), and Fio and Leighton (1994) indicate that groundwater pumping was an important water source for communities on the San Francisquito fan until the mid-1960s, when purchased water became the primary source. Groundwater still remains a significant water source in some communities on the San Francisquito fan, such as Atherton.

Groundwater exploitation prior to the mid-1960s resulted in lowered groundwater elevations in Palo Alto, Menlo Park and Atherton (Metzger 2002), movement of saline water inland from San Francisco Bay (Iwamura 1980), and land subsidence in parts of Palo Alto and East Palo Alto (Poland and Ireland 1988). Groundwater levels are thought to have recovered since the mid-1960s. However, groundwater elevation data are limited near San Francisquito Creek and it is difficult to assess whether elevations are now similar to those at the end of the nineteenth century or whether they remain depressed. The limited information available (see maps in Fio and Leighton 1994) suggests that historic ground water elevations were below the local streambed on the upper part of the fan, resulting in similar losses of streamflow to groundwater to those observed now.

Groundwater elevations may have been closer to the streambed along the lower part of San Francisquito Creek, resulting in more frequent surface flows in the past than occur there now. Note that streambed incision in the upper end of San Francisquito Creek and aggradation along the lower reaches over the past century may have also affected the extent of infiltration and groundwater influence along San Francisquito Creek.

Much less is known of groundwater levels in the upper watershed. Crippen and Waananen (1969) note that groundwater elevations are typically well below the surface in small tributaries to San Francisquito Creek in the Bay Foothills, although they may rise to streambed levels following intense winter storms. Little is known of the groundwater conditions in the upper watershed. Here, shallow soils over bedrock on the valley slopes limit the extent of groundwater storage and its influence on streamflow. However, groundwater may be an important component of streamflow along the valleys of the San Andreas Fault Zone where deep alluvial deposits may store considerable volumes of water.

2.5 Sediment Transport

Certainly, the longest record of sediment yield is from deposition in Searsville Lake by Corte Madera, Sausal, and Alambique Creeks. Repeated reservoir surveys provide average sediment deposition from 1892 to 1913; 1913 to 1929; 1929 to 1946; 1946 to 1995; and from 1995 to 2000 (nhc *et al* 2002). Note that deposition in the reservoir underestimates total sediment transport from the Searsville watershed. This occurs for two reasons. First, the finest grain sizes are carried over Searsville Dam to San Francisquito Creek so they are not included in the total, and second, coarse sediment that has accumulated on the fans of Corte Madera, Sausal and Martin Creeks upstream of the reservoir has not been surveyed, except between 1995 and 2000 (nhc *et al* 2002). The sediment that passes over the dam amounts to about 10% of the incoming load; adjustments for deposition on fans at the head of the lake can only be prepared for the most recent period.

Table 3 summarizes deposition volumes and calculated denudation rates in the Searsville Lake watershed and provides estimated transport for Corte Madera and for the other tributaries to Searsville Lake. The pattern of sediment transport is similar to that of annual flows. Very large volumes were transported during the early part of the twentieth century and from 1995 to 2000; sediment transport seems to have been at a lower average rate in the intervening years. Long-term average denudation rates are reasonably consistent with the long-term uplift rate in the northern Santa Cruz Mountains.

Landslides, debris flows, bank erosion, and channel incision in the Santa Cruz Mountains appear to contribute most of the sediment that is carried to Searsville Lake. These sources are active infrequently, particularly during severe storms and earthquakes.

Brown and Jackson (1973) report on a suspended sediment sampling program at the Stanford gage for the period from 1962-1969. Annual loads at the station can be assumed to be nearly entirely from Los Trancos and Bear Creeks and they provide an indication of historic suspended (fine) loads from these two subwatersheds. Additional measurements were collected at this gauge during the 1998 water year to compare to the previous sediment-rating curve (nhc *et al* 2002).

Table 3 summarizes annual suspended loads reported by Brown and Jackson and calculated denudation rates in Bear and Los Trancos watersheds. Denudation rates on Los Trancos and Bear watersheds are highly variable from year to year but average – reflecting the occurrence of landslides and channel erosion during large storms – but average much lower than observed in Corte Madera Creek watershed. This is consistent with the patterns of landsliding and other sediment sources in the Santa Cruz Mountains.

3. WATERSHED CHARACTERISTICS

3.1 Background

The watershed boundaries developed by the Geologic Survey's Western Region Geoscience Center have been used for this study as the basis for describing watershed characteristics. Because these watershed boundaries provide the framework for an extensive GIS database that inventories physical and social features within the watershed (USGS 2003), it was determined that using the same boundaries for this study would facilitate incorporating new information into the existing database. The boundaries delineate major subwatersheds for the large tributaries to San Francisquito Creek and further sub-divide the tributary subwatersheds into sub-subwatersheds. The San Francisquito watershed is composed of 10 subwatersheds: San Francisquito, Corte Madera, Los Trancos, Alambique, Martin, Sausal, Westridge, Bear, Bear Gulch, and West Union Creeks. Additionally, for the purposes of this analysis, the subwatersheds were further divided into sub-subwatersheds based on hydrologic characteristics. Table 4 summarizes the size and stream lengths of the subwatersheds and sub-subwatersheds within this system.

3.2 Reach Division and Description

After a review of existing stream classification systems, it was determined that the Montgomery and Buffington (1993) stream classification system, referred to here as the Montgomery-Buffington method, would best characterize and classify the stream morphology of the San Francisquito Watershed. The Montgomery-Buffington method was selected over other potential classification systems because of its suitability to the project area and the project needs. Key advantages of the Montgomery-Buffington method are:

- The Montgomery-Buffington method was developed for mountainous watersheds of the Pacific Coastal Ecoregion, an area that covers approximately 2300 miles of coastal watersheds along the western edge of North America from the Santa Cruz Mountains to Anchorage, Alaska.
- The Montgomery-Buffington method was designed for use in forested mountain watersheds where there is a significant large woody debris (LWD) component to stream bed morphology.
- The Montgomery-Buffington method can be applied at a reconnaissance level using aerial photographs and topographic maps. Although preferable, field surveys are not required for application to watersheds where only limited physical data are available.
- The Montgromery-Buffington method is a process-based approach designed for application in watershed-scale studies that assess channel form and response to natural and human disturbance.

MONTGOMERY-BUFFINGTON METHOD DESCRIPTION

The Montgomery-Buffington method uses a process-based, watershed-scale approach to characterize changes in channel morphology, sediment transport dynamics, and response potential of streams to natural and human disturbance. A process-based approach identifies the relationship between channel morphology and transport processes, including inflowing water and sediment, hydraulic conditions, and spatial and temporal changes in local factors which affect channel form such as land use, riparian cover, or instream bedrock controls.

The Montgomery-Buffington method identifies three main morphologic scales; the watershed, the valley segment, and the channel reach. Watersheds are divided into two basic categories; hillslopes and valley segments. Valley segments are located along the drainage network and are divided into *colluvial*[1], *bedrock*, and *alluvial*[2] types. *Colluvial* valley segments exist predominantly in the upper watershed and are often dominated by debris flow and landslide processes. Sediment supply exceeds sediment transport capacity and soil creep, tree throw, and slope instability are primary ways sediment is introduced into the channel network. Sediment in colluvial channel beds is commonly less sorted than in downslope channels. In contrast, sediment transport capacity exceeds supply in *bedrock* valley segments, resulting in the transport of available material through the reach, exposing bedrock, or mostly bedrock, along the channel. *Alluvial* valley segments are those where streams and rivers flow through alluvium, characterized by unconsolidated fluvially deposited sediment.

Alluvial and colluvial valley segments are characterized by a range of stream types that, in the Pacific Coastal Ecoregion, commonly present as a sequential transition of fluvial styles with distance downstream (Figure 1). The Montgomery-Buffington method proposes that each stream type represents a stable morphology for the given sediment supply and available sediment transport capacity of the reach. Table 5 provides a brief description of each stream type. Note that gradient divisions between stream types in Table 5 are not absolute. Rather, transitions between types are gradual such that some reaches may exhibit features of multiple stream types.

CLASSIFICATION OF PHYSICAL STREAM CHARACTERISTICS

The Montgomery-Buffington Method was used to classify stream types in the San Francisquito watershed. Although field inspection is the preferred approach for channel classification, watershed size and time constraints did not allow us to visually inspect all stream channels in the watershed. Instead, a reconnaissance-level classification was conducted using several data sources, namely: stream slope data collected from a digital elevation model (DEM), air photos, field inspections of Corte Madera Creek conducted by nhc for this study, and reported stream observations from other authors. Frey (2001) documented river morphology on all streams draining into Searsville Lake; Smith and Harden (2001) walked and reported observations on major streams draining the Bear Creek subwatershed during an inspection of obstructions to fish passage; Royston Hanamoto Alley and Abey (2000) compiled a detailed assessment of geomorphic conditions along San Francisquito Creek from Junipero Serra Blvd. to Highway 101; and nhc *et al* (2002) assessed geomorphic conditions on San Francisquito Creek downstream of Searsville Dam. No field inspections of streams in the Los Trancos Creek watershed were identified in the available literature.

---

[1] Colluvium - a general term applied to loose and incoherent deposits, usually at the foot of a slope or cliff and brought there chiefly by gravity (Dictionary of Geological Terms, 1984)

[2] Alluvium - a general term for detrital deposits made by streams on river beds, flood plains, and alluvial fans (Dictionary of Geological Terms, 1984)

Using the DEM information in a GIS, streams in the San Francisquito watershed were divided into segments based on the slope ranges identified in Figure 1. Predicted stream types from the Montgomery-Buffington method were then assigned to each slope class to provide a preliminary assessment of stream types in the watershed (Figure 2). Note that the legend excludes Regime ($S < 0.001$) and Bedrock ($0.30 > S > 0.001$) stream types. The only area to exhibit a Regime channel morphology is located in the estuary of San Francisquito Creek, downstream of Highway 101 where the creek is tidal, whereas bedrock stream types are possible in all slope environments and must be validated by field inspection. Note that slopes in Figure 2 are averaged, typically over several hundred meters depending on slope variability, and represent a typical slope for stream segments in each sub-subwatershed.

The validity of predicted results from the Montgomery-Buffington method was assessed by comparison with field observations of channel reaches at the sub-subwatershed scale (Table 6). The Los Trancos subwatershed and some reaches of the Bear Creek subwatershed are excluded from Table 6 due to a lack of field inspection reports for these areas. Predicted and observed stream types in Table 6 are representative of what is typical for each sub-subwatershed. Some stream sections may and likely do exhibit variations that are atypical and differ from the stream types identified in Table 6.

Examination of Table 6 shows that, although there are some differences, predicted stream types from the Montgomery-Buffington method show good correlation with field observations. Predicted stream types were observed in 26 of the 29 sub-subwatersheds; however, more than just the predicted stream type(s) was observed in 16 of these 26 sub-subwatersheds. Thus, observed stream types were often more varied than what was predicted. In all of these cases, additional observed stream types were one class above or below the predicted type. This is not unusual given that slopes were averaged along stream segments in each sub-subwatersheds. Consequently, some stream reaches exhibit slopes and therefore stream types that are greater or less than the average.

There were three occurrences where some or all of the predicted stream types were not observed, namely: sub-subwatersheds CM-12, BG-3, and CM-6 (Table 6). In each case, a colluvial stream type was either predicted or observed. In CM-12 and CM-6, cascade stream types were predicted for these sub-subwatersheds whereas colluvial channels were observed due to abundant landslide activity. In sub-subwatershed BG-3 a colluvial stream type was predicted but not observed. This is due to an omission. The steep tributary stream to Bear Gulch associated with the colluvial stream type in Figure 2 was omitted from the field inspection and thus could not be compared with the predicted type (Table 6).

4. LAND USE

4.1 Background

Of the approximately 27,400 acres of the San Francisquito watershed, approximately 8,798 acres are protected by public agencies, property easements, or private land trusts (32.1%), providing a natural feel within much of the watershed. The west side of the watershed is largely unpopulated, consisting primarily of forest and grasslands. The headwaters of the watershed originate in the Santa Cruz mountains within the western side of the watershed, and drain into Los Trancos Creek. Corte Madera Creek and West Union Creek also largely drain protected areas that support forested habitats. The lower watershed is highly urbanized, and supports expansive areas of residential and commercial development. Although development is prevalent when compared to the western portion of the watershed, large, contiguous areas of open space, including forest, rangeland and agricultural areas, are interspersed throughout the urban land uses, complementing the undeveloped, open nature of much of the watershed.

4.2 Existing Conditions

To examine the existing land uses throughout the watershed, a number of land use classification systems were reviewed in order to identify the system that would best classify the watershed into land use categories for analysis. Because the Santa Clara and San Mateo County general plans use different classification system, it was necessary to use a classification system that was contiguous throughout the entire watershed. In addition, the Department of Water Resources land use classification system was reviewed, but because of the lack of detail it was determined that this system did not meet the needs of the project. It was determined that the system developed by the Association of Bay Area Governments (ABAG) in 1995 provided the most comprehensive and thorough system for describing the watershed. This system was developed in 1995 for the entire San Francisco Bay area, including San Francisquito watershed. The spatial resolution (1 hectare) of the data provides a suitable scale for analysis of existing land use conditions throughout the watershed. ABAG updates this data set every 5 years, and identifies changes in land uses through aerial photography review and mapping at a 1:3,000 scale, followed by ground-truthing on a 1:24,000 scale basemap. In areas where access is limited, including those lands owned by public agencies, property easements, or private land trusts, the Bayareaap data, developed by the GreenInfo Network, was used supplement mapping. This information was last updated in 2001. The JPA is currently in the process of obtaining the latest set of land use data to be included in future versions of this document. For analysis purposes in this document, land use information is from the 1995 mapping effort.

Table 7 summarizes the existing land uses within the San Francisquito watershed. The dominant land uses are forest, rangeland, and residential development. As described above, the majority of forest and rangeland exist in the western portion of the watershed, while the residential development is dominant in the eastern portion of the watershed. As of this 1995 land use analysis, development within the watershed consisted of 29.6

percent residential, 5.2 percent industrial/commercial, and 65.1 percent agriculture or open space.

4.3 Historical Trends

Throughout time, the San Francisquito watershed has continued to increase in the area that supports commercial and residential development, as part of the ever-growing larger San Francisco Bay Area. Review of historic and current aerial photos and maps indicate a steady growth in area of development, particularly in the eastern portion of the watershed where the topography is more gently sloping. In conjunction with the increasing areas of development, the roadways system has continued to expand, both in size and complexity throughout the watershed. Figures 3 through 5 show the changes in both land uses and roadways from 1899 to 1948 and then to 1993. In addition, Table 8 documents the change in paved and unpaved roadways throughout the watershed from 1868 to 1999. Table 8 also includes the number intersections between roadways and streams within the watershed, showing the steady increase in stream interactions with development over time in many of the sub-watersheds.

The Santa Clara Basin Watershed Management Initiative (WMI) has also projected future residential, industrial, and commercial development within the watershed through the year 2020 based on trends over time throughout the watershed, and in the surrounding areas. Although development will continue to increase over time throughout the watershed, only 8,149 acres are available for development, leaving a substantial portion of the watershed in a relatively natural condition. The projected increase in development is shown in Table 9. Increased development directly results in changes in the area of impervious surfaces within the watershed also, changing runoff patterns, water quality, and flood capacities over time. The projected increase in impervious surfaces as a result of projected development is shown in Table 10.

5. BIOLOGICAL RESOURCES

5.1 Background

The biological resources within the San Francisquito watershed have been separated into terrestrial and aquatic species and habitat types, and are described below. These descriptions are based on a number of previous studies and databases, including the "Fishes and Amphibians of the San Francisquito Creek and Matadero Creek Watersheds", completed by Stanford University in 2000, the "Biotic Assessment of Upper Searsville Lake and the Lower Floodplain of Corte Madera Creek" completed by Standford University in 1996, "Juvenile Steelhead/Rainbow Trout Surveys in Los Trancos Creek", completed by David Vogel in 2002, the "Distribution and Ecology of Stream Fishes in the San Francisco Bay Drainage" completed by R. A. Leidy in 1984, "Adult Steelhead Passage in the Bear Creek Watershed", completed by Jerry Smith and Deborah Harden of San Jose State University, the "Wateshed Characteristics Report" completed by the Santa Clara Basin Watershed Management Initiative in 2001, the "California Natural Diversity Database", which is on-going and managed by the California Department of Fish and Game, and the "California Wildlife-Habitat Relationships System and GAP Analysis Mapping", completed by the U.S. Forest Service and U.C. Santa Barbara in 1988.

5.2 Terrestrial Habitat Types

The California Wildlife-Habitat Relationships (WHR) system was used to classify habitat types within the San Francisquito watershed because it is broad in nature, and provides a uniform system throughout the entire watershed. The WHR system has mapped generalized vegetation communities throughout California, and draws correlations to wildlife species that utilize these areas. This system was selected for the purposes of this study because mapping encompasses the entire watershed area. Local studies, the California Department of Fish and Game Natural Diversity Database, and field verification were used to determine more specific wildlife and habitat correlations for special-status species that are know to occur, or thought to occur, within the watershed. This information is described below under the special-status species section. Figure 6 shows the WHR habitat classifications by subwatersheds. Acreages for each habitat type by subwatershed are shown in Table 11.

ANNUAL GRASSLAND

Annual grassland habitats are open grasslands composed primarily of annual plant species. Introduced annual grasses are the dominant plant species within this habitat throughout the watershed. This habitat type fluctuates throughout the year with rainfall levels and temperature variations, growing rapidly in the spring, dying off in the summer, and slowly growing over the fall and winter months. In addition, grazing is permitted in many portions of the watershed, keeping grasses low to the ground. Vegetation within this habitat type includes wild oats, ripgut brome, popcorn flower, true clover, Crystal Springs lessingia serpentine bunchgrass, fragrant fritillary, Franciscan onion and California poppy. Wildlife species that utilize annual grasslands include the western fence lizard, common garter snake, western rattlesnake, California ground squirrel, Botta's pocket gopher, western harvest mouse, western meadowlark, turkey vulture, and northern harrier.

COASTAL OAK WOODLAND

Coastal oak woodland habitat consists of an overstory dominated by deciduous and evergreen hardwoods with scattered conifers. The vegetation within this habitat type is dominated by coastal live oak, and also includes California bay, madrone, valley oak, blue oak, and digger pine. Typical understory plants generally consist of California blackberry, fiesta flower, miner's lettuce, robust monardella, and legenere. Wildlife species found throughout this habitat include California red-legged frog, California tiger salamander, gopher snake, western pond turtle, red-tailed hawk, western meadowlark, acorn woodpecker, northern harrier, California ground squirrel, raccoon, pallid bat, and Bay checkerspot butterfly.

CHAMISE-REDSHANK CHAPARREL

Chamise-redshank chapparrel habitat within the watershed is mature in nature, and generally consists of single layered chaparral habitat lacking a well-developed herbaceous groundcover and overstory trees. This habitat type is dominated by chamise and redshank vegetation, and supports jackrabbits, cottontail rabbits, ground squirrels, wood rats, pocket mice, and several sparrows and hawks.

MONTANE HARDWOOD

The montane hardwood habitat is mature in nature, and consists of a pronounced hardwood tree layer, with a poorly developed shrub stratum, and a sparse herbaceous layer throughout the watershed. Douglas fir, California black oak, Digger pine, knobcone pine, and coast live oak are abundant within this habitat type. The understory consists of scattered woody shrubs, including manzanita, poison-oak, and western leatherwood. Wildlife species found within this habitat include scrub jay, Steller's jay, acorn woodpecker, saltmarsh common yellowthroat, western gray squirrel, California ground squirrel, dusky-footed woodrat, western fence lizard, and western rattlesnake.

REDWOOD

The redwood habitat within the watershed consists entirely of secondary growth, creating an even-aged tree structure. Dominant vegetation within this habitat includes coast redwood, Pacific madrone, douglas fir, and California buckeye. Understory vegetation is diverse, and generally consists of deer fern, California huckleberry, California red huckleberry, coyotebush, snowbrush ceanothus, Santa Cruz manzanita and western fescue. Wildlife that are often found within this habitat type include California red-legged frog, California tiger salamander, peregrine falcon, gray squirrel, Steller's jay, and deer mouse.

URBAN

Vegetation within urban environments varies greatly depending on the level and type of development. Development types within the San Franciscquito watershed include industrial, commercial, and residential development, interspersed with open space and park areas. Street tree strips are common within the highly developed portions of the watershed. Shade trees and lawns are common in residential areas. Vegetation is dominated by ornamental species that are used for landscaping purposes within these areas. Common wildlife species found within the urban environment include house sparrow, rock dove, scrub jay, house finch, raccoon, opossum, and striped skunk.

A number of sensitive habitats are found within the urban environment as mapped by the WHR system. Within the urban areas of the watershed, a number of riparian corridors line the streams of the watershed. Tree species that occur within the riparian corridor include valley oak, coast live oak, willows, and California buckeyes. Common riparian shrubs include coffeeberry, ocean spray, and creeping snowberry. These areas provide suitable habitat for a number of sensitive species, including California red-legged frog, California tiger salamander, western pond turtle, and, within the streams, steelhead. In addition, areas of coastal salt marsh habitat are included within the urban classification towards the mouth of the watershed where San Francisquito Creek meets the San Francisco Bay. The salt marsh habitat is dominated by cordgrass, pickleweed, and salt grass. This habitat type also supports a number of sensitive species, including the Point Reyes Bird's beak, Congdon's tarplant, salt-marsh harvest mouse, black rail and California clapper rail.

5.3 Aquatic Resources

The San Francisquito watershed supports a wide variety of aquatic resources, including a healthy run steelhead. This section provides an overview of existing conditions, historic trends and an overview of existing steelhead use of the watershed.

HISTORIC TRENDS

Recent fish sampling within the San Francisquito watershed include six native species and seven nonnative species. Native fish captured included the California roach, Sacramento sucker, hitch, speckled dace, threespine stickleback, and prickly sculpin. Three additional species of native fish were present historically, but are not thought to occur within the watershed presently. These include the Sacramento perch, last collected in 1960, the squawfish, last collected in 1905, and the white prickly sculpin, of which the last capture date is unknown.

As the human population increased throughout the Santa Clara Valley in the 1940s, dramatic declines in native fish populations were observed. Within the watershed, diversions and dams have been built, and increased development and changes in land uses have changed flow patterns through channelization and implementation of flood control patterns. This has resulted in increased erosion and sedimentation, a reduction in riparian habitats, and increased flow velocities throughout the watershed. These changes have degraded fish spawning and rearing habitat, particularly in riffle habitats, and decreased water quality for aquatic insect reproduction, food sources, and overall survival. In addition, the destruction of riparian vegetation has increased water temperature through a reduction in shade, and decreased the amount of organic material and ponded areas throughout the watershed through a reduction in woody debris and rootwads. Consequently, the native fish that remain in the watershed are restricted to the more natural headwaters of the western portion of the watershed, or are tolerant to a wide range of environmental conditions. Table 12 provides an overview of native fish that have been found throughout the watershed over time through a variety of studies. In addition, Table 13 show the native fish that were historically found in the watershed, and both native and invasive fish now found throughout the watershed.

EXISTING CONDITIONS

Within the San Francisquito watershed, nonnative fish populations outnumber native fish populations in many of the subwatersheds, particularly in the eastern section of the watershed. This is due to the western section of the watershed remaining less disturbed than the eastern subwatersheds. In addition, many of the tributaries that flow from the western portion of the watershed flow from protected open spaces and natural areas. The aquatic habitat in the western portion of the watershed continues to flow through areas that are largely forested, and are bordered by high quality riparian corridors. Therefore, water temperatures remain cool, woody material remains abundant, and levels of dissolved oxygen in the water remain high. Riffles in this area provide spawning habitat for many fish, cover for juvenile fish, and habitat for aquatic insects that provide a healthy food source for a variety of fish. Within the eastern portion of the watershed, two small reservoirs within the San Francisquito watershed have been constructed that block the upstream migration of fish. Reservoirs also replace flowing water habitat, replacing it with lake like conditions that are static in nature. These habitats are often higher in temperature, lower in dissolved oxygen, and calmer in nature than the flowing streams that they replaced. These altered environmental conditions are often more suitable for non-native fish than existing native populations. The introduction of nonnative fish populations often results from stocking waterways with fish for recreational fishing enhancement, introduction of species that control mosquito populations, pet releases, or accidental introductions. Often, these introduced species thrive in their new environments, and through competition and predation, lead to decreases in native fish populations.

STEELHEAD POPULATIONS

Portions of the San Francisquito watershed support a stable steelhead population. Because much of the watershed is located within steep terrain, or within lands that have been protected, high quality habitat has remained throughout the Los Trancos and Bear Creek subwatersheds. In addition, San Francisquito Creek, downstream of Searsville Dam through the Lagunita Diversion, provides quality steelhead habitat. Downstream of this area, the quality of steelhead habitat diminishes greatly. However, high sedimentation and erosion levels throughout the San Francisquito watershed associated with development and human disturbance greatly constrain aquatic habitat for steelhead spawning and rearing. In addition, flood control infrastructure and roadways have contributed to barriers for steelhead migration throughout the watershed, described below under the passage and barriers section. As development continues in the eastern portion of the watershed, efforts must be made to preserve the existing passageway to preserve the existing downmigrating juvenile steelhead and upmigrating adult steelhead.

STEELHEAD PASSAGE BARRIERS

A number of steelhead passage barriers have been constructed throughout the San Francisquito watershed. These barriers include roadways, bridge aprons and drops, dams, log and debris jams, weirs, culverts, pipes and waterfalls. A number of these barriers have been identified through previous studies throughout the watershed. Within the Bear Creek, Bear Gulch and West Union Creek subwatersheds, stream passage barriers have been identified and ranked in severity, and recommendations for alleviating each have been provided (Smith and Harden, 2001). In addition, the Santa Clara Valley Water District (District) Coordinated Resource Management Plan is now starting to inventory stream passage barriers throughout the watershed. Figure 7 identifies existing stream intersections with roadways and trails that may present fish passage barriers throughout the watershed. This information will be supplemented with additional fish passage barrier information that is currently being compiled into a GIS database by USGS.

A number of efforts have been made to increase fish passage throughout the watershed. In 1978, the non-functional fish ladder at the Lake Lagunita Diversion Dam was replaced with a Denil-style fishway to alleviate a major fish passage barrier within the watershed. In addition, a fish ladder was installed in the Los Trancos Creek watershed on the Felt Lake Diversion Dam in 1995 to alleviate the fish passage problems within the creek. Searsville Dam continues to provide a terminal barrier on San Francisquito Creek, in the lower portion of the watershed. Although a number of fish passage barriers have been removed and/or alleviated throughout the system, further studies and inventories are necessary to further improve steelhead migration corridors throughout the watershed.

5.4 Special-Status Species

A number of special-status species are known to occur, or have potential to occur, throughout the San Francisquito watershed. The California Department of Fish and Game Natural Diversity Database has identified a number of known occurrences. This information has been supplemented with habitat evaluation to determine suitability for special status species by Jones & Stokes biologists. A brief description of these species, and associated habitats, is provided below.

The mouth of the watershed meets the San Francisco bay in salt marsh habitat which provides suitable habitat for the salt marsh harvest mouse, California clapper rail, and black rail, which have all been observed within, or within the immediate vicinity of, the bottom of the watershed. Moving west through the watershed as water becomes less tidally influenced and salinity levels decrease, riparian corridors are present along many of the streams throughout the watershed. These areas provide suitable habitat for the California red-legged frog, California tiger salamander, and western pond turtle, which have all been observed within the watershed. Additionally, streams within the Bear

Creek and San Francisquito watersheds provide suitable migration and spawning habitat for steelhead trout that have been observed in both of these areas. Throughout the watershed, a number of serpentine soil outcrops have been identified within the San Francisquito, Searsville Lake, Bear Creek, and West Union Creek sub-watersheds. This micro-habitat supports a number of special status and common wildlife and plant species that have been observed at these areas, including the Bay checkerspot butterfly, serpentine bunchgrass, and Crystal Springs lessingia.

6. RIPARIAN CORRIDOR MANAGEMENT POLICIES & PROGRAMS

6.1 Overview

Riparian corridors that border streams throughout the watershed provide habitat for a number of special-status and common wildlife and plant species. These areas support a number of native tree species, including the valley oak, coast live oak, red willow, sandbar willow and California buckeye. In addition, a number of native shrub species are found within these corridors, including coffeeberry, ocean spray and creeping snowberry. In addition, riparian corridors provide food and habitat for wildlife species, minimize erosion, sedimentation and runoff into local waterbodies, increase the flood capacity of local waterbodies, and add to the aesthetic, natural surroundings within the watershed. In order to preserve the diversity of wildlife and plant species throughout the watershed as development continues throughout the watershed, it is essential to continue to study and protect these areas.

The WMI study mapped riparian corridors throughout the San Francisquito watershed. The study used the definition of riparian corridors earlier defined in the City of San Jose's Riparian Restoration Action Plan, completed in 1999. This definition states "...any defined stream channels including the area up to the bankfull flow line, as well as all riparian (streamside) vegetation in contiguous adjacent uplands. Characteristic woody riparian vegetation species could include (but are not limited to): willow, alder, box alder, Fremont cottonwood, bigleaf maple, western sycamore and oaks. Stream channels include all perennial and intermittent streams shown as a solid or dashed blue line on USGS topographic maps, and ephemeral streams or arroyos with well-defined channels and some evidence of scour or deposition". This mapping was then overlaid with the ABAG 1995 land use data, described above under the *Land Use* section, to determine land uses throughout the watershed within riparian corridors. Table 14 shows the results of this analysis. As can be seen from this table, a large area of riparian corridors are protected and support natural land uses, including wetlands, forest, rangleland and freshwater habitats. In contrast, a nearly equal area of riparian habitat is located in residential, urban recreation, agricultural and urban land uses. For this reason, a number of studies and policies have been developed local government agencies to guide future planning and development near these sensitive areas, which are described below.

Additional riparian mapping has been completed for the San Francisquito Creek portion of the watershed, completed as part of the San Mateo Countywide Stormwater Pollution Prevention Program (Bernhard, et. Al, 1999). Because this mapping was limited to a small portion of the watershed, the analysis for this report is focused on the broader mapping effort that was undergone as part of the WMI study.

6.2 Local Land Use and Development Policies

San Francisquito Creek, which lies in the lower end of the watershed, is located within the District's Lower Peninsula Flood Control Zone and San Mateo County's San Francisquito Creek Flood Control Zone. Because recent flood events have occurred in 1955, 1958, 1982, 1995, and 1998, efforts have been made to improve flooding and bank erosion within this creek system. Efforts have included protecting existing riparian vegetation, whenever possible, to improve flood capacities and bank erosion within the waterway. In contrast to this, areas have been lined with sacked concrete, or protected with berms and low floodwalls. Efforts to implement flood control measures that include natural components, including enhancing or restoring riparian vegetation, are also being looked at and implemented throughout the waterway.

Additionally, a CRMP process has been under way since 1993 for the entire San Francisquito watershed. This process includes over 30 organizations that are dedicated to preserving the natural resources, and in particular riparian corridors, throughout the watershed. A CRMP Draft Management Plan and Reconnaissance Investigation Report of the watershed that identified alternatives for addressing flood and erosion issues throughout the watershed were completed. This process is continuing as local fisheries, wildlife resources, and land uses are identified and studies throughout the watershed.

While studies continue to be performed throughout the watershed to determine future actions that will enhance and protect riparian corridors throughout the watershed, local policies that have been developed by both Santa Clara and San Mateo counties continue to be implemented. These policies guide local development, recreation, and flood control planning to both support the missions of the counties and protect the sensitive riparian corridors throughout the watershed. These policies have been summarized in Table 15.

6.3 Stream Maintenance and Management

OVERVIEW

The management and maintenance of the local drainage systems within the San Francisquito watershed is the responsibility of several local agencies including the District, the San Mateo County Flood Management District, and the cities of Palo Alto, Menlo Park, and East Palo Alto. In 1999 these entities formed the San Francisquito Creek Joint Powers Authority (JPA) to coordinate flood protection, creek maintenance, and habitat protection and restoration activities along the creek and within the watershed.

A variety of flood management and drainage facilities are found within the watershed including storm drains that convey storm water runoff from adjacent developed areas, and reservoirs such as Searsville Lake that provide incidental flood storage and management. For example, Metzger (2002) identified and mapped 12 storm drains with diameters greater than 30 inches along San Francisquito Creek between Junipero Serra Boulevard and the Palo Alto Municipal Golf Course. Additionally, the lower main stem of San Francisquito Creek has been modified (i.e., concrete and/or rock lined, leveed) in areas to prevent bank erosion/failure, increase the ability of the creek channel to convey floodwater, and to reduce the threat of flooding to adjacent developed areas. Management and maintenance of these facilities is the responsibility of the city public works departments and the District. Specific information on routine stream maintenance activities conducted by the District is provided below.

SANTA CLARA VALLEY WATER DISTRICT STREAM MAINTENANCE PROGRAM

The District is a special purpose governmental agency responsible for providing water supply and flood protection for Santa Clara County in an environmentally responsible manner. The District manages streams, canals, reservoirs, dams, pipelines, groundwater percolation facilities, and water treatment plants throughout the county. The District's jurisdiction on a stream begins at the point where 320 acres (1/2 square mile) of watershed drain to the stream, and continues downstream to San Francisco Bay.

The District routinely conducts maintenance activities (e.g., sediment and vegetation removal, bank protection) on streams and canals within its jurisdiction to meet flood protection and water supply mandates, provide access and flood protection, and protect property. Recently, the District developed and approved the Stream Maintenance Program (SMP) to provide specific programs to effectively implement individual routine stream maintenance projects. The SMP specifies procedures for maintenance design, field operations and Best Management Practices (BMPs), and includes a regional mitigation program to mitigate cumulative wetland and riparian impacts (SCVWD 2001).

Routine stream maintenance activities addressed in the SMP include:

- **Sediment Removal.** The District typically removes sediment in areas where sediment deposition has: 1) reduced flood conveyance capacity; 2) impeded function of facilities and/or structures (e.g., flap gates, culverts); or 3) impede fish passage and/or access to fish passage structures.
- **Vegetation Management.** The District typically removes vegetation in and adjacent to streams and canals to: 1) maintain flood conveyance capacity; 2) maintain water conveyance for supply purposes; 3) reduce fuel loads on adjacent banks to meet local fire code requirements; and 4) control invasive nonnative vegetation. Specific vegetation management activities conducted the District are based on site-specific environmental conditions, but generally include mowing, discing, hand clearing, or herbicide application.
- **Bank Protection.** Bank protection activities are typically conducted by the District to repair eroding stream banks or to implement preventative erosion protection. The District implements bank protection in areas where erosion and bank failure could: 1) cause significant property damage; 2) pose a public safety concern; 3) negatively affect transportation; 4) negatively affect beneficial use of surface water; or 5) negatively affects riparian habitat. Bank protection measures implemented by the District are based on site-specific conditions and range from the installation of "hard" structures (e.g., rock, concrete, sack concrete, gabion baskets) to the use of "soft" structures (e.g., brush mattresses, root wads, crib walls).

Within the San Francisquito watershed, stream maintenance activities routinely conducted by the District are limited to the main stem of San Francisquito Creek and primarily include vegetation removal and herbicide application.

6.4 Non-Native Species Control

Because nonnative species dominate much of the watershed, particularly in the lower portion of the watershed, a number of plans and policies have been developed by local entities to control further invasion by these species. Invasive, nonnative plant species have come to dominate many of the riparian corridors throughout the watershed. These include blue gum eucalyptus, acacia, fennel, periwinkle, English ivy, French broom, black locust, Algerian ivy and Cape ivy. In order to control these species, the CRMP process have produced the *Streamside Planting Guide for San Mateo and Santa Clara County Streams* to guide local landowners with planting selection, highlighting the benefits of incorporating native species into local landscapes. In addition, the District routinely removes non-native vegetation, in conjunction with the SMP.

6.5 Designated Watershed Beneficial Uses

In consultation with state and local government entities, the Regional Water Quality Control Board designates existing and potential beneficial land uses for waterbodies within the San Francisco Bay area. These beneficial uses were identified and defined in the 1995 Water Quality Control Plan for the San Francisco Bay Basin (basin plan). Within the San Francisquito watershed, beneficial uses have been identified for San Francisquito Creek, Searsville Lake, and Felt Lake. Table 16 summarizes the beneficial land uses that have been identified for these watersbodies. Definitions and objectives for each land use, taken from the basin plan, are described below.

AGRICULTURAL SUPPLY (AGR)

The definition of agricultural supply states "Uses of water for farming, horticulture, or ranching, including, but not limited to, irrigation, stock watering, or support of vegetation for range grazing." The objectives for this standard are to set limits for soluble salt accumulation, chemical composition changes in local soils, toxicity of crops, and disease transmission through the use of reclaimed water.

COLDWATER FRESHWATER HABITAT (COLD)

The definition of cold freshwater habitat states "Uses of water that support coldwater ecosystems, including, but not limited to, preservation or enhancement of aquatic habitats, vegetation, fish, or wildlife, including invertebrates". The objectives for this standard are set to protect coldwater habitats for both anadromous and local fisheries, including setting standards for temperature, toxicity, and dissolved oxygen.

FISH MIGRATION (MIGR)

The definition of fish migration states "Uses of water that support habitats necessary for migration, acclimatization between freshwater and saltwater, and protection of aquatic organisms that are temporary inhabitants of waters within the region". The objectives for this standard are set to protect anadromous fish, particularly fish passage barriers. Thermal, physical, and chemical barriers are all monitored, as well as tidal movement and river flows to ensure adequate environments for migratory fish and offspring.

WATER CONTACT RECREATION (REC-1)

The definition of water contact recreation states "Uses of water for recreational activities involving body contact with water where ingestion of water is reasonably possible. These uses include, but are not limited to, swimming, wading, water-skiing, skin and scuba diving, surfing whitewater activities, fishing, and uses of natural hot springs". The objectives for this standard are set to protect human health (e.g. water borne disease transmission) through the control of the concentration of bacteria in water bodies, standards for taste and odor, and standards on floating material.

NON-CONTACT WATER RECREATION (REC-2)

The definition of non-contact water recreation states "Uses of water for recreational activities involving proximity to water but not normally involving contact with water where water ingestion is reasonably possible. These uses include, but are not limited to, picnicking, sunbathing, hiking, beachcombing, camping, boating, tide pool and marine life study, hunting, sightseeing, or aesthetic enjoyment in conjunction with the above activities". The objectives for this standard are set to protect recreators engaging in non-water contact activities that are associated with local water bodies, and are set to protect and promote human well-being through protecting habitats and aesthetic features from odors or floating material.

FISH SPAWNING (SPWN)

The definition of fish spawning states "Uses of water that support high quality aquatic habitats suitable for reproduction and early development of fish". The objectives for this standard are to maintain and enhance water bodies that support fish spawning habitat through regulating water temperature, size distribution and organic content of sediments, water depth, and current velocity.

WARM FRESHWATER HABITAT (WARM)

The definition of warm freshwater habitat states "Uses of water that support warm water ecosystems including, but not limited to, preservation or enhancement of aquatic habitats, vegetation, fish, or wildlife, including invertebrates". The objectives for this standard are to maintain warm freshwater habitats through the regulation of temperature, dissolved oxygen, pH, and turbidity within local water bodies for the protection of a variety of wildlife species, including bass, bluegill, perch, frogs, crayfish and insects.

WILDLIFE SPECIES (WILD)

The definition of wildlife species states "Uses of waters that support wildlife habitats, including, but not limited to, the preservation and enhancement of vegetation and prey species used by wildlife, such as waterfowl". The objectives for this standard are to maintain dissolved oxygen, pH, alkalinity, salinity, turbidity, settleable material, oil, toxicants and disease organisms to protect riparian and wetland habitats that support a diverse array of wildlife species.

7. REFERENCES

Association of Bay Area Governments. 1995. GIS Database of Land Use Data. Oakland, CA.

Bates, R.L. and J.A. Jackson (eds), 1984. Dictionary of Geological Terms (3rd ed.), Doubleday, New York, 571 p.

Bernhard, J., E. Gilmartin, M. Rigney, and K. Sipes. 1999. San Francisquito Creek riparian habitat project report. Prepared for the San Mateo Countywide Stormwater Pollution Prevention Program. Coyote Creek Riparian Station. Alviso, CA.

Brabb, E., R. Graymer and D. Jones. 2000. Geologic map and map databases of the Palo Alto 30' X 60' Quadrangle, California. USGS Miscellaneous Field Studies Map MF-2332 and Pamphlet. 30 pp.

California Department of Fish and Game. 2003. California Natural Diversity Database. Sacramento, CA.

California Regional Water Quality Control Board. 1995. Water quality control plan, San Francisco Bay basin. San Francisco Regional Water Quality Control Board, Oakland, CA.

Corps of Engineers. 1972. Survey report on San Francisquito Creek, San Mateo and Santa Clara Counties, California, for flood control and allied purposes. U.S. Army Engineer District, San Francisco, California. 27 pp.

Crippen, J. and A. Waananen. 1969. Hydrologic effects of suburban development near Palo Alto, California. USGS Open-File Report. 121 pp.

Cushing, K.K. 1999. After the flood waters receded: Assessing the economic effects of San Francisquito Creek February 1998 flooding. US Army Corps of Engineers and Santa Clara Valley Water District.

Fee, C., A. Launer, and S. Rottenborn. 1996. Biotic assessment of upper Searsville Lake and the lower floodplain of Corte Madera Creek. Submitted to Philippe Cohen at the Jasper Ridge Biological Preserve. Center for Conservation Biology, Stanford University, and Stanford, CA.

Fio, J and D. Leighton. 1995. Geohydrologic framework, historical development of the ground-water system, and general hydrologic and water-quality conditions in 1990, south San Francisco Bay and peninsula area, California. USGS Open-File Report 94-357. 46 p.

Frey, C. 2001. Geomorphic study of Searsville Lake Watershed, Portola Valley, California. M.Sc Thesis, San Jose State University. 137 pp.

Helley, E, K. Lajoie, W. Spangle and M. Blair. 1979. Flatland deposits of the San Francisco Bay Region, California – their geology and engineering properties and their importance to comprehensive planning. USGS Professional Paper 943. 88 pp.

Iwamura, T.I. 1980. Saltwater intrusion investigation in the Santa Clara County baylands area, California. Santa Clara Valley Water District. 115 p.

Launer, A. and G Holtgrieve. 2000. Fishes and amphibians of the San Francisquito Creek and Matedero Creek Watersheds, Stanford University: Report on 1998 & 1999 Field Activities. Center for Conservation Biology, Stanford University, Stanford, CA.

Leidy, R. A. 1984. Distribution and ecology of stream fishes in the San Francisco Bay Drainage. Hilgardia. A Journal of Agricultural Science Published by the California Agricultural Experiment Station. 28 pp.

Metzger, L. 2002. Streamflow gains and losses along San Francisquito Creek and, characterization of surface-water and ground-water quality, Southern San Mateo and Northern Santa Clara Counties, California, 1996-97. USGS Water-Resources Investigations Report 02-4078. 28 pp.

Metzger, L. and J. Fio. 1997. Ground-water development and the effects on ground-water levels and water quality in the town of Atherton, San Mateo County, California. USGS Water-Resources Investigation 97-4033. 31 p.

Montgomery, D.R. and J.M. Buffington. 1993. Channel classification, prediction of channel response, and assessment of channel condition, Report TFW-SI-110-93-002, Washington State Timber/Fish/Wildlife Agreement, University of Washington, Seattle, 107 p.

Northwest Hydraulic Consultants, Balance Hydrologics, Inc, H.T. Harvey & Associates, Jones & Stokes, Dr. Matt Kondolf and Dr. Jerry Smith. 2002. Searsville Lake sediment impact study. Stanford University, Facilities Operation. 186 p and Appendices.

Northwest Hydraulic Consultants and Jones & Stokes Associates. 1999. Family Farm Road flood and sediment control study. Phase 2 – Schematic Design Plan. Stanford University, Facilities Operation.

Owens, J., S. Chartrand and B. Hecht. 2002. Annual hydrologic record and sediment yield, Los Trancos Creek, Portola Valley, California: Data report for Water Year 2001. Balance Hydrologics, Inc for Stanford University, Facilities Operations Dept.

Poland, J. and R. Ireland. 1988. Land subsidence in the Santa Clara Valley, California, as of 1982. USGS Professional Paper 497-F. 61 p.

Royston, Hanamoto, Alley and Abey, Philip Williams & Associates, H.T. Harvey & Associates, Environmental Science Associates and Frederick T. Seher & Associates.

2000. San Francisquito Creek bank stabilization and revegetation: existing conditions report. Prepared for City of Menlo Park, City of Palo Alto, City of East Palo Alto, Santa Clara Valley Water District and County of San Mateo. 121 pp.

San Mateo County. 1986. San Mateo county general plan. San Mateo County, Department of Environmental Management, Planning and Building Division, San Mateo County, CA.

Santa Clara Basin Watershed Management Initiative. 2001. Watershed characteristics report. Watershed Management Plan, Volume One (Unabridged). Prepared by the Santa Clara Basin Watershed Management Initiative, which is a stakeholder group organized to protect and enhance the Santa Clara Basin watershed. February 2001.

Santa Clara County. 1994. Santa Clara county general plan: charting a course for Santa Clara County's future, 1995-2010. Santa Clara County, Planning Division, San Jose, CA.

Santa Clara Valley Water District. 2001. Draft environmental impact report and stream maintenance program report for the multi-year stream maintenance program.

Smith, J.J. and D. Harden. 2001. Adult Steelhead passage in the Bear Creek Watershed. San Francisquito Watershed Council.

Sokol, D. 1964. The hydrogeology of the San Francisquito Basin, San Mateo and Santa Clara Counties, California. Unpublished Ph.D Dissertation. Stanford University, Palo Alto. 238 p.

U.S. Forest Service and U.C. Santa Barbara. 1998. Wildlife-Habitat Relationship System and GAP Analysis Mapping. Santa Barbara, CA.

U.S. Geological Survey. 2002. Streamflow gains and losses along San Francisquito Creek and characterization of surface-water and ground-water quality, Southern San Mateo and Northern Santa Clara Counties, California, 1996-97.

Vogel, D. 2002. Juvenile steelhead/rainbow trout (*Oncorhynchus mykiss*) surveys in Los Trancos Creek, March – May 2002. Red Bluff, CA.

Wentworth, C., S. Graham, R.J. Pike, G. Buekelman, D. Ramsey and A. Barron. 1997. Summary of distribution of slides and earth flows in San Mateo County, California. USGS Open-File Report 97-745C. 10 p and 11 sheets.

Tables

Table 1: Stream Gages Operated on San Francisquito Creek and Tributaries

Gage Name	Gage Number	Period of Record	Area (mi^2)	River Mile [1]
At Searsville Dam (staff gage on spillway crest)	None	1892-1913	--	12.7
At Stanford University	11164500	1931 to 1941; 1950 to present	37.5	7.6
At Menlo Park	11165000	1931-1941	38.3	5.4
At Palo Alto	11165500	1934-36	38.4	4.6
Los Trancos Ck near Stanford University	11163000	1930-41	--	--
Los Trancos Tributary near Stanford University	11163200	1958-66	0.42	--
Los Trancos Ck at Stanford University	11163500	1930-41	7.46	--

[1] River mileage along San Francisquito Creek from Corps of Engineers (1972)

Table 2: Large Water Management Structures on San Francisquito Creek and Associated Tributaries

Structure Name	Purpose	Capacity (acre-feet)	Year Built	Operation [1]
Searsville Lake	Irrigation	About 250 [1]	1890	No longer operated; historically, flashboards installed in spring; removed in fall
Felt Lake	Irrigation	1,000	1930	Not known
Lagunita Lake	Recreation	360	1900	Water diverted from San Francisquito Ck in spring; drained in summer
Bear Gulch Reservoir	Domestic	660	1896	Not known

[1] Remaining capacity as of nhc *et al* (2002).

Table 3: Annual Transport Volumes and Denudation Rates in San Francisquito Watershed

A. Searsville Lake Deposition

Period	Annual Deposition (ac-ft/yr)	Watershed Area (km^2)		Denudation Rate (mm/year) [1]		
		Searsville	Corte Madera	Total	Corte Madera [2]	Remainder
Searsville Lake Deposition						
1892 to 1913	17.4	35.9	16.1	0.66	1.20	0.23
1913 to 1929	3.6	35.9	16.1	0.14	0.25	0.05
1929 to 1946	7.2	35.9	16.1	0.27	0.50	0.09
1946 to 1995	7.1	35.9	16.1	0.27	0.49	0.09
1995 to 2000	23.5	35.9	16.1	0.89	1.62	0.31
Average (1892 to 2000)	*9.4*	*35.9*	*16.1*	*0.36*	*0.65*	*0.12*
Total Searsville Lake and Fan Deposition						
1995 to 2000	43.4	35.9	16.1	1.49	2.69	0.51

[1] Assumes that the annual deposition represents 90% of total; 10% over dam crest (see nhc*et al* 2002)

[2] Assumes that Corte Madera provides 81% of total load (see nhc*et al* 2002)

[3] Assumes that 1 dam^3 = 1.23 acre-feet

B. Annual Suspended Load (Brown and Jackson 1973)

Period	Annual Transport (tons)	Annual Volume [4] (ac-ft)	Watershed Area (km^2) [5]	Denudation Rate (mm/year) [5]		
				Total	Bear	Los Trancos
1962	1,880	0.9	49.7	0.01	0.01	0.01
1963	18,700	8.6	49.7	0.14	0.15	0.13
1964	1,100	0.5	49.7	0.01	0.01	0.01
1965	10,500	4.8	49.7	0.08	0.08	0.07
1966	1,100	0.5	49.7	0.01	0.01	0.01
1967	50,600	23.2	49.7	0.38	0.40	0.35
1968	2,700	1.2	49.7	0.02	0.02	0.02
1969	34,200	15.7	49.7	0.26	0.27	0.23
Total	*120,800*					
Average Suspended Load from Bear and Los Trancos Creeks [6]						
	15,100	6.9	49.7	0.11	0.12	0.10

[4] Assumes 1.35 tons/yd^3; 1,613 yd^3/acre-foot

[5] Assumes area of Los Trancos watershed is 7.61 mi^2; that of Bear Creek is 11.57 mi^2

[6] Average suspended load is average for 1962 to 1969 at the San Francisquito Creek gauge; assumes 64% from Bear; 36% from Los Trancos (nhc *et al* 2002).

Table 4. Subwatershed and Sub-Subwatershed Acreages and Stream Lengths

Subwatershed	Sub-Subwatershed	Area (acres)	Stream Length (feet)
San Francisquito Creek	SF-1 to SF-12	8,577	82,160
	SF-1	1,047	15,450
	SF-2	1,320	0
	SF-3	833	11,012
	SF-4	648	3,020
	SF-5	372	1,866
	SF-6	243	0
	SF-7	417	0
	SF-8	999	8,597
	SF-9	496	2,859
	SF-10	247	5,976
	SF-11	1,944	32,170
	SF-12	13	1,210
Corte Madera Creek	CM-1 to CM-12	4,366	62,765
	CM-1	811	8,810
	CM-2	589	7,459
	CM-3	378	6,976
	CM-4	361	5,905
	CM-5	251	3,497
	CM-6	283	3,969
	CM-7	337	5,682
	CM-8	117	2,808
	CM-9	237	3,215
	CM-10	86	1,446
	CM-11	357	5,745
	CM-12	560	7,253
Los Trancos Creek	LT-1 to LT-7	4,870	87,229
	LT-1	405	8,771
	LT-2	555	13,049
	LT-3	534	16,010
	LT-4	649	10,225
	LT-5	920	15,138
	LT-6	1,000	14,723
	LT-7	807	9,313
Alambique Creek	AC-1	1,492	13,524
Martin Creek	MC-1	790	8,420
Sausal Creek	SC-1 to SC-6	1,547	30,225
	SC-1	381	4,798
	SC-2	409	8,151
	SC-3	138	3,414
	SC-4	231	5,938
	SC-5	280	5,864
	SC-6	107	2,060
Westridge Creek	SL-1 to SL-2	1,547	30,225
	SL-1	523	3,082
	SL-2	556	11,049
Bear Creek	BC-1 to BC-2	1,582	24,652
	BC-1	618	5,537
	BC-2	964	19,115
Bear Gulch	BG-1 to BG-3	2,250	38,643
	BG-1	428	8,838

Subwatershed	Sub-Subwatershed	Area (acres)	Stream Length (feet)
	BG-2	1,239	17,713
	BG-3	583	12,092
West Union Creek	WUC-1 to WUC-11	3,575	73,248
	WUC-1	170	1,558
	WUC-2	242	6,556
	WUC-3	139	2,215
	WUC-4	271	7,313
	WUC-5	192	3,179
	WUC-6	528	12,872
	WUC-7	281	3,895
	WUC-8	543	9,343
	WUC-9	272	7,468
	WUC-10	64	2,068
	WUC-11	875	16,781

Table 5. Summary of Valley Segment and Reach Types in the Montgomery Buffington Method

Valley Segment Type	Reach Type	Location in Watershed	Typical Slope Range	Primary Sediment Process	Instream Sediment Storage	Notes
Colluvial	Unchanneled (Hollow)	Upper	S > 0.2	Supply	N/A	Hollows are located in the uppermost sections of the drainage network. There is insufficient flow to form a channel but sediment accumulates in hollows over years or decades and, during infrequent large storm or seismic events, mass wasting processes such as a debris flow and landslides convey this sediment into the drainage network. The cycle begins again with the hollow gradually refilling with sediment.
Colluvial	Channeled	Upper / Middle	S > 0.2	Supply	High	These stream channels characterize the uppermost streams in a watershed. Colluvial processes (slope failure) dominate sediment production and channel morphology in these reaches; landslides, debris flows, and soil creep are common. Sediment supply is abundant and sediment throughput is transport limited. Bed material is typically unsorted, containing abundant fine-grained material due to limited stream flows.
Alluvial	Cascade	Upper	0.3 > S > 0.1	Transport	Very Low	Cascade channels are very steep and exhibit very coarse bed material (up to boulder sizes). Higher stream flows in these reaches appear as white-water, tumbling around larger boulders and cobbles. Sediment storage is very limited and restricted to low-velocity areas in small pools or behind debris jams. These channels can maintain their configuration for decades, until very large storms re-mobilize the stream bed.
Alluvial	Step-Pool	Middle	0.1 > S > 0.03	Transport	Low / Medium	Step-pool channels exhibit alternating pools and steps (steep, often vertical, drops usually located near a bed control such as a very large boulder or a debris jam). Steps typically contain very coarse bed material whereas pools allow finer material to accumulate, providing some sediment storage.
Alluvial	Plane-Bed	Middle	0.03 > S > 0.01	Transport	Low / Medium	Plane-bed channels exhibit a relatively flat bed that lacks significant variability and has few bedforms. Occasional steps, pools, or rapids may form but are infrequent or absent. Bed material is typically coarse and the bed is armored. Plane-bed channels may be either supply or transport limited.
Alluvial	Pool-Riffle	Middle / Lower	0.02 > S 0.001	Transport / Deposition	Medium / High	Pool-riffle channels exhibit significant morphologic variability. The bed alternates between steeper (riffle) sections with coarse bed material to shallower sloping pool sections where fine sediments accumulate and are stored until the next high flow. Instream bars are regularly observed and act as additional sediment storage sites. Pool-riffle channels are considered to be transport limited during flood flows.
Alluvial	Regime	Lower	S < 0.001	Deposition	High	Regime channels are characterized by low-slope environments and predominantly sand bed material. Channel roughness is low and sediment is transport limited at all flow stages.
Bedrock	Bedrock	Upper / Middle	0.30 > S > 0.001	Transport	Low	Bedrock channels are largely devoid of bed material. They have high transport capacities and, other than local pockets of sediment accumulation, are scoured to bedrock of all available sediment.

Table 6. Comparison of Results from Montgomery Buffington Method and Field Observations

Sub-Subwatershed	Location in Watershed	Average Stream Slope (%)	Predicted Reach Type(s)	Observed Reach Type(s)	Field Observations
CM-1	Middle	1 - 2	Pool-Riffle Plane-Bed	Pool-Riffle Plane-Bed	(CM-1 & CM-2) The creek exhibits pool-riffle-run bed morphology and is entrenched. Bank erosion is less than in areas upstream, caused in part by gabions and concrete walls that reduce erosion. Landslides average 2.5 per stream kilometer and there no major debris jams. Channel aggradation increases downstream toward Searsville Lake. (Source: this study; Frey 2001)
CM-2	Middle	2 - 3	Plane-Bed	Step-Pool Plane-Bed Pool-Riffle	
CM-3	Upper	10 - 20	Cascade	Step-Pool Cascade Colluvial Bedrock	The gulch is very steep and confined by steep side slopes. Many areas of bedrock outcrop along the bed. The gulch exhibits a step-pool morphology in its downstream section whereas bedrock, colluvial, and cascade reaches are reported upstream. Boulders and bedrock outcrops are prominent influences on stream morphology. (Source: this study; Frey 2001)
CM-4	Upper	10 - 20	Cascade	Step-Pool Cascade Colluvial Bedrock	Jones Gulch is similar to Hamms Gulch. Bedrock controls are common and some sections of the gulch exhibit bedrock reaches where the creek has carved a canyon into rock and polished it clean of sediment. (Source: this study; Frey 2001)
CM-5	Upper	3 - 10	Step-Pool	Pool-Riffle Plane-Bed Step-Pool	The creek is entrenched and exhibits step-pool and pool-riffle-run bed morphology. The stream bed is very coarse, boulders and rock outcrops are prominent influences on channel morphology and restrict bank erosion. Small sections of floodplain are observed. (Source: this study; Frey 2001)
CM-6	Upper	10 - 20	Cascade	Colluvium Bedrock	The creek flows largely on bedrock above 1240 ft elevation whereas the reach is colluvial downstream. A large debris flow is observed at the mouth of the creek. Active and abundant erosion is a prominent feature along the creek, particularly below 1240 ft elevation. Landslides are very common, about 35 per stream kilometer. (Source: this study; Frey 2001)
CM-7	Upper	3 - 10	Step-Pool	Step-Pool	The creek is entrenched and exhibits a step-pool morphology. Occasional small gravel bars are observed as well as small areas of floodpain. Many areas of unweathered bedrock appear along the banks, preventing erosion. About 5 landslides and 7 debris jams are observed per stream kilometer, less than areas upstream. (Source: this study; Frey 2001)
CM-8	Upper	10 - 20	Cascade	N/A	Available field inspections have only examined the mouth of this gulch. Reports state that it appeared to be stable, have low bank erosion, and was not a major sediment contributor to the watershed. (Source: Frey 2001)

Sub-Subwatershed	Location in Watershed	Average Stream Slope (%)	Predicted Reach Type(s)	Observed Reach Type(s)	Field Observations
CM-9	Upper	20 - 30	Cascade Colluvial	Step-Pool Cascade	This creek exhibits a cascade morphology above 1400 ft elevation followed by a step-pool morphology downstream. Little active erosion is observed in the cascade reach whereas significant erosion of high banks is observed in the step-pool reach. About 16 landslides and 15 debris jams are observed per stream kilometer. (Source: Frey 2001)
CM-10	Upper	3 - 10	Step-Pool	Step-Pool	The creek is entrenched and exhibits a step-pool morphology with some small areas of floodplain. Small lateral bars are occasionally observed along the channel bed. Bedrock is commonly observed along the channel banks, reducing bank erosion. Landslides and debris jams are less frequent than upstream reaches, about 5 landslides 7 debris jams per stream kilometer. (Source: this study; Frey 2001)
CM-11	Upper	10 - 20	Cascade	Cascade Colluvial Bedrock	The creek exhibits a bedrock and colluvial morphology above the 1600 ft elevation with extensive bedrock control along the bed; bank erosion is light to moderate. From 1600 ft elevation to 1300 ft, resistant bedrock creates a cascade morphology. Below 1300 ft steep sideslopes and shallow landslides contribute large volumes of sediment to the channel and it maintains a colluvial morphology with about 9 debris jams per stream kilometer. Shallow landslides occur frequently, about 28 per stream kilometer. (Source: Frey 2001)
CM-12	Upper	10 - 20	Cascade	Colluvial	Frequent landsliding, about 29 per stream kilometer, dominates the steep sideslopes and stream morphology of this colluvial channel environment. The channel is aggraded in many areas with landslide material. Bedrock outcrops are very infrequent. (Source: this study; Frey 2001)
BC-1	Middle	<1 - 2	Pool-Riffle Plane-Bed	Pool-Riffle Plane-Bed	Pool-Riffle morphology is observed throughout this reach. Larger pools exhibit silty bed material. The channel is entrenched in many areas but the banks are relatively stable. (Source: Smith and Harden 2001)
BG-1	Middle	<1 - 2	Pool-Riffle Plane-Bed	Pool-Riffle Plane-Bed	Pool-Riffle morphology is observed throughout this reach. (Source: Smith and Harden 2001)
BG-2	Upper	3 - 20	Step-Pool Cascade	Step-Pool Cascade	A step-pool morphology with some cascade reaches are observed in this reach. Cobbles and coarse gravels are the dominant bed material. Much of the channel is deeply entrenched. (Source: Smith and Harden 2001)
BG-3	Upper	10 - 30	Cascade Colluvial	Step-Pool Cascade	A step-pool morphology with some cascade reaches are observed on the Bear Gulch main stem. The reach is described as steep, boulder channel. No observations are available for side channels in this sub-subwatershed (Source: Smith and Harden)
WUC-1	Upper	<1	Pool-Riffle	Pool-Riffle Plane-Bed	Pool-Riffle-Run morphology is observed throughout this reach. Silt is commonly observed at the bottom of larger pools. (Source: Smith and Harden 2001)
WUC-3	Upper	1 - 2	Pool-Riffle Plane-Bed	Pool-Riffle Plane-Bed	Pool-Riffle-Run morphology is observed throughout this reach. Silt is commonly observed at the bottom of larger pools. (Source: Smith and Harden 2001)

Sub-Subwatershed	Location in Watershed	Average Stream Slope (%)	Predicted Reach Type(s)	Observed Reach Type(s)	Field Observations
WUC-5	Upper	1 - 2	Pool-Riffle Plane-Bed	Pool-Riffle Plane-Bed	Pool-Riffle-Run morphology is observed throughout this reach. Silt is not commonly observed in pools. (Source: Smith and Harden 2001)
WUC-6	Upper	3 - 20	Step-Pool Cascade	Step-Pool Cascade	This reach is steep and deeply entrenched. Bed material consists largely of cobbles and boulders. (Source: Smith and Harden 2001)
WUC-7	Upper	2 - 10	Plane-Bed Step-Pool	Plane-Bed Step-Pool	A descriptions consistent with Step-Pool and Plane-Bed channel morphology are given for this reach. Upstream sections are steeper than downstream areas and exhibit smaller and less frequent pools. (Source: Smith and Harden 2001)
WUC-8	Upper	10 - 20	Cascade	Step-Pool Cascade	A description consistent with Step-Pool and Cascade morphology is given for this reach. This reach is very steep and exhibits logjams and falls in steeper sections. (Source: Smith and Harden 2001)
WUC-10	Upper	1 - 2	Pool-Riffle Plane-Bed	Pool-Riffle Plane-Bed	Pool-Riffle-Run morphology is observed throughout this reach. Silt is commonly observed at the bottom of larger pools. (Source: Smith and Harden 2001)
SF-1	Lower	<<1	Pool-Riffle Regime	Regime Pool-Riffle Plane-Bed	Regime morphology is observed downstream of Highway 101. The channel is tidally influenced, very low in slope, and exhibits a sandy bed. Upstream of Highway 101 pool-riffle-run morphology with few riffles is observed within a confined and entrenched channel cross-section. (Source: nhc *et al* 2002; RHAA 2000)
SF-3	Lower	<1	Pool-Riffle	Pool-Riffle Plane-Bed	Pool-riffle-run morphology with few riffles is observed within a confined and deeply entrenched channel cross-section. Instream sand and gravel bars are frequently observed. (Source: nhc *et al* 2002; RHAA 2000)
SF-4	Lower	<1	Pool-Riffle	Pool-Riffle Plane-Bed	Pool-riffle-run morphology is observed within a confined and deeply entrenched channel cross-section. Instream sand and gravel bars are frequently observed. (Source: nhc *et al* 2002; RHAA 2000)
SF-9	Lower	<1	Pool-Riffle	Pool-Riffle Plane-Bed	Pool-riffle-run morphology is observed within a confined and deeply entrenched channel cross-section. Instream sand and gravel bars are frequently observed. (Source: nhc *et al* 2002; RHAA 2000)
SF-10	Middle	<1 - 2	Pool-Riffle Plane-Bed	Pool-Riffle Plane-Bed Bedrock	Pool-riffle-run morphology is observed within a confined and deeply entrenched channel cross-section. Bedrock appears irregularly along the bed and lower banks and is a dominant control on channel morphology. (Source: nhc *et al* 2002)
SF-11	Middle	<1 - 2	Pool-Riffle Plane-Bed	Pool-Riffle Plane-Bed Bedrock	Pool-riffle-run morphology is observed within a confined and deeply entrenched channel cross-section. Bedrock is prominent along the bed and lower 5 ft of both banks and is a dominant control on channel morphology. Most flows do not rise above the bedrock contact. (Source: nhc *et al* 2002)
SF-12	Middle	1 - 10	Pool-Riffle Plane-Bed Step-Pool	Pool-Riffle Plane-Bed Step-Pool Bedrock	The bed is armoured downstream of the dam and exhibits a step-pool morphology before transitioning to a pool-riffle-run morphology further downstream. The channel is confined and deeply entrenched. Bedrock is prominent along the bed and lower 5 ft of both banks and is a dominant control on channel morphology. Most flows do not rise above the bedrock contact. (Source: nhc *et al* 2002)

Table 7. Acreage of Existing Land Uses for the San Francisquito Watershed

Land Uses	**Acreage**
Residential, 4 or more DU/acre	2,027
Residential, 1 to 3 DU/acre	6,074
Residential, 1 DU/2 to 5 acres	25
Commercial	495
Public/Quasi-Public	707
Industry – Heavy	18
Transportation, Communication	217
Utilities	2
Agriculture	490
Forest	12,267
Rangeland	4,100
Urban Recreation	425
Vacant, Undeveloped	396
Wetlands	101
Fresh Water	72
Total	*27,416*

(Source: ABAG Land Use Data 1995)

Table 8. Subwatershed Stream and Road Intersections Over Time

	1868-1899			1953-1955			1968			1999		
Subwatershed	**Paved Roads (miles)**	**Unpaved Roads (miles)**	**Stream/Road Intersections**	**Paved Roads (miles)**	**Unpaved Roads (miles)**	**Stream/Road Intersections**	**Paved Roads (miles)**	**Unpaved Roads (miles)**	**Stream/Road Intersections**	**Paved Roads (miles)**	**Unpaved Roads (miles)**	**Stream/Road Intersections**
San Francisquito Creek	0	57	6	149	9	24	192	14	24	194	14	33
Los Trancos Creek	0	11	3	17	8	26	31	15	26	36	15	26
Corte Madera Creek	0	17	0	16	10	13	28	14	13	36	15	16
West Union Creek	0	14	1	11	10	24	15	10	24	16	10	24
Bear Gulch	0	4	1	9	7	7	9	7	7	9	8	7
Bear Creek	0	6	0	20	1	10	26	2	10	26	2	12
Sausal Creek	0	5	0	9	6	11	11	9	11	12	9	11
Alambique Creek	0	6	0	5	11	4	7	12	4	7	12	4
Westridge Creek	0	1	0	4	3	2	7	4	2	7	4	2
Martin Creek	0	2	0	7	2	2	9	3	2	9	3	2

Table 9. Projected Residential, Industrial, and Commercial Development for the San Francisquito Watershed

Land Use Type	Land Available for Development (acres)	Land Projected for Development (acres)	Percentage of Available Land Projected for Development	Percentage of Watershed Projected for Development	Percent Buildout
Residential	8,090	1,666	21	36	59
Industrial/ Commercial	59	35	60	5	97
Total	*8,149*	*1,701*	*81*	*41*	*64*

(Source: Watershed Management Initiative 2001)

Table 10. Existing and Projected Percent Imperviousness for San Francisquito Watershed (1995)

Year	Existing/Projected Acreage of Impervious Surfaces within Watershed	Existing/Projected Percent of Impervious Surfaces within Watershed
1995	5700	20.8
2020	7200	26.1

(Source: Watershed Management Initiative 2001, ABAG Land Use Data 1995)

Table 11. Habitat Types within Subwatersheds

Subwatershed	Habitat Acreages					
	Annual Grassland	Coastal Oak Woodland	Chamise-Redshank Chaparral	Montane Hardwood	Redwood	Urban
San Francisquito Creek	741	425				7313
Corte Madera Creek	517	1455		1204		1189
Los Trancos Creek	443	1294	745			2385
Alambique Creek		408		44	622	416
Martin Creek				49	467	272
Sausal Creek	25	234		122	252	911
Westridge Creek		261		438		378
Bear Creek	182	12				1387
Bear Gulch		560			1102	586
West Union Creek	26	166			3003	379

(Source: UCSB GAP Analysis, 1988)

Table 12. Occurrence of Fish in Collections from the San Francisquito Creek Drainage, 1855-1981

Species	Cutts 1855	Agassiz 1860	Hughs 1890	Snyder 1938	Shapovalov 1938	Grant and Stanton 1939	SJSU 1956-1957	CDFG 1966	CDFG 1974-1976	CDFG 1978-1979	Leidy 1981
Native Species											
Salmo gairdnerii	X			X	X				X	X	X
Lavinia symmetricus				X	X	X		X	X		X
Ptchocheilus grandis				X							
Gasterosteus aculeatus				X	X	X	X	X	X		X
Catastomus occidentalis			X	X					X	X	X
Archoplites interruptus		X									
Cottus asper				X	X		X		X		
Cottus gulosus											X
Nonnative Species											
Carassius auratus									X		
Lepomis cyanellus							X	X	X		
Lepomis macrochirus										X	
Micropterus salmoides							X				
Gambusis affinis											X
Lucania parva											X
Ictalurus nebulosus							X				
Percentage of Native Species	**100**	**100**	**100**	**100**	**100**	**100**	**40**	**66**	**71**	**66**	**71**

(Source: Distribution and Ecology of Stream Fishes in the San Francisco Bay Drainage, 1984)

Table 13. Historic and Current Freshwater Fish of the San Franciscquito Watershed

Historical Freshwater Fish	Current Freshwater Fish
Native Species	
Coho salmon (*Oncorhynchus kisutch*)	Speckled Dace (*Rhinichythys osculus*)
Rainbow/Steelhead trout (*Oncorhynchus mykiss*)	Rainbow/Steelhead Trout (*Oncorhynchus mykiss*)
California roach (*Lavinia symmetricus*)	California Roach (*Lavinia symmetricus*)
Sacramento sucker (*Catostomus occidentalis*)	Sacramento Sucker (*Catostromus occidentalis*)
Threespine stickleback (*Gasterosteus aculeatus*)	Threespine Stickleback (*Gasterosteus aculeatus*)
Prickly sculpin (*Cottus asper*)	Prickly Sculpin (*Cottus asper*)
Riffle sculpin (*Cottus gulosus*)	Riffle Sculpin (*Cottus gulosus*)
Chinook salmon (*Onchorhyhyrichus tshawytscha*)	Hitch (*Lavinia exilicauda*)
Sacramento pikeminnow (*Ptychocheilus grandis*)	
Sacramento perch (*Archopites interruptus*)	
Exotic Species	
	Rainwater Killifish (*Lucania parva*)
	Mosquitofish (*Gamusia affinis*)
	Bluegill sunfish (*Menidia audens*)
	Pumpkinseed (*Lepomis gibbosus*)
	Green sunfish (*Lepomis cyanellus*)
	Black crappie (*Pomoxis nigromaculatus*)
	Largemouth bass (*Micropterus salmoides*)
	Redear sunfish (*Lepomis microlophus*)

(Source: Watershed Management Initiative 2001)

Table 14. Land Use Acreages within Riparian Corridors within San Francisquito Watershed

Land Use Type	Acreage
Forest	906
Residential	561
Rangeland	130
Vacant/Undeveloped	75
Agriculture	70
Urban Recreation	50
Wetlands	40
Public/Quasi-Public	20
Commercial	19
Transportation/Communication	15
Freshwater	14
Heavy Industrial	4

(Source: Watershed Management Initiative 2001, ABAG Land Use Data 1995)

Table 15. Riparian Policies from Santa Clara and San Mateo County General Plans

Santa Clara County	
Urban Growth and Development – 6	Hazard and resource areas, including riparian corridors, shall be considered unsuitable for urban development
Urban Resource Conservation – 2	The County shall provide leadership in efforts to protect or restore valuable natural resources, such as wetlands, riparian areas, and woodlands
Urban Resource Conservation – 19	The strategies for maintaining and improving water quality on a county wide basis, in addition to ongoing point source regulation, should include restoration of wetlands, riparian areas, and other habitats which serve to improve Bay water quality
Urban Resource Conservation – 31	Areas of habitat richest in biodiversity and necessary for preserving threatened or endangered species should be formally designated to receive greatest priority for preservation, including baylands and riparian areas, serpentine areas, and other habitat types of major significance
Rural Parks and Recreation – 14	Privately owned recreational land uses and facilities within rural unincorporated areas, including but not limited to golf courses, campgrounds, and similar uses, should be compatible with the landscape and resources of the areas in which they are proposed. To ensure such compatibility, potentially significant impacts often associated with such land uses should be avoided or reduced to less than significant levels, including riparian areas
Rural Resource Conservation – 2	The County shall provide leadership in protecting and restoring valuable natural resources, such as wetlands, riparian areas, and others, for County-owned lands and by means of multi-jurisdictional endeavors
Rural Resource Conservation - 31	Natural streams, riparian areas, and freshwater marshes shall be left in their natural state providing for percolation and water quality, fisheries, wildlife habitat, aesthetic relief, and educational or recreational uses that are environmentally compatible
Rural Resource Conservation – 32	Riparian and freshwater habitats shall be protected through the following general means: a. setback of development from the top of the bank b. regulation of tree and vegetation removal c. reducing or eliminating use of herbicides, pesticides, and fertilizers by public agencies d. control and design of grading, road construction, and bridges to minimize environmental impacts and avoid alteration of the streambed and stream banks e. protection of endemic, native vegetation
Rural Resource Conservation – 35	Flood control modifications to be made in streams that have substantial existing natural areas should employ flood control designs which enhance riparian resources and avoid to the maximum extent possible significant alternation of the stream, it's hydrology, and its environs
Rural Resource Conservation – 36	In cluster residential developments or other projects where open space dedication is required, the stream, riparian areas, and freshwater marshes should be included within the restricted open space area of the project or protected by other enforceable mechanisms, such as deed restrictions or conservation easements

Rural Resource Conservation – 39	Within areas immediately adjacent to the stream buffer area, new development should minimize environmental impacts on the protected bummer area, and screening of obtrusive or unsightly aspects of a project should be considered as a means of preserving the scenic value of riparian areas
Rural Resource Conservation – 40	Where new roads, clustered residential development, or subdivisions are proposed in proximity of streams and riparian areas, they should be designed so that riparian vegetation is retained
Rural Resource Conservation – 41	Where trails and other recreational uses are proposed by adopted plans to be located in the vicinity of streams and riparian areas or reservoirs, trail alignments and other facilities should be placed on the fringe of the riparian buffer area or at an appropriate distance to avoid disturbance of the stream or vegetation
Rural Resource Conservation – 54	Restoration of stream channels and riparian areas should be encouraged wherever feasible. Multiple users, such as for recreational trails, should be considered so long as habitat and other ecological values are preserved
Rural Health and Safety – 31	Flood control measures should be considered part of an overall community improvement program and should advance the goal of preserving and enhancing riparian vegetation and habitats
San Mateo County	
Role of the County 1.47 Develop Guidelines for Vegetation and Debris Control in Riparian Corridors	Develop guidelines for vegetation and debris control in riparian corridors. Such guidelines should set forth clear direction on procedures to: 1) facilitate the abatement of avoidable flood hazards and 2) minimize adverse impacts on riparian communities
Role of the County 1.48 Encourage the Management of Riparian Corridors	Encourage, and to the maximum extent feasible, reward the efforts of those responsible for managing riparian corridors in a manner that is consistent with County and State Guidelines
Rural Site Planning 4.26 Water Bodies	b. Discourage structures which would adversely impact the appearance of a stream and associated riparian habitat
General Policies 15.45 Abatement of Flooding Hazards	Support measures for the abatement of flooding hazards, including debris clearance and silt removal programs conducted in a manner so as not to disrupt existing riparian communities

(Source: Santa Clara County General Plan (1994) and San Mateo County General Plan (1986))

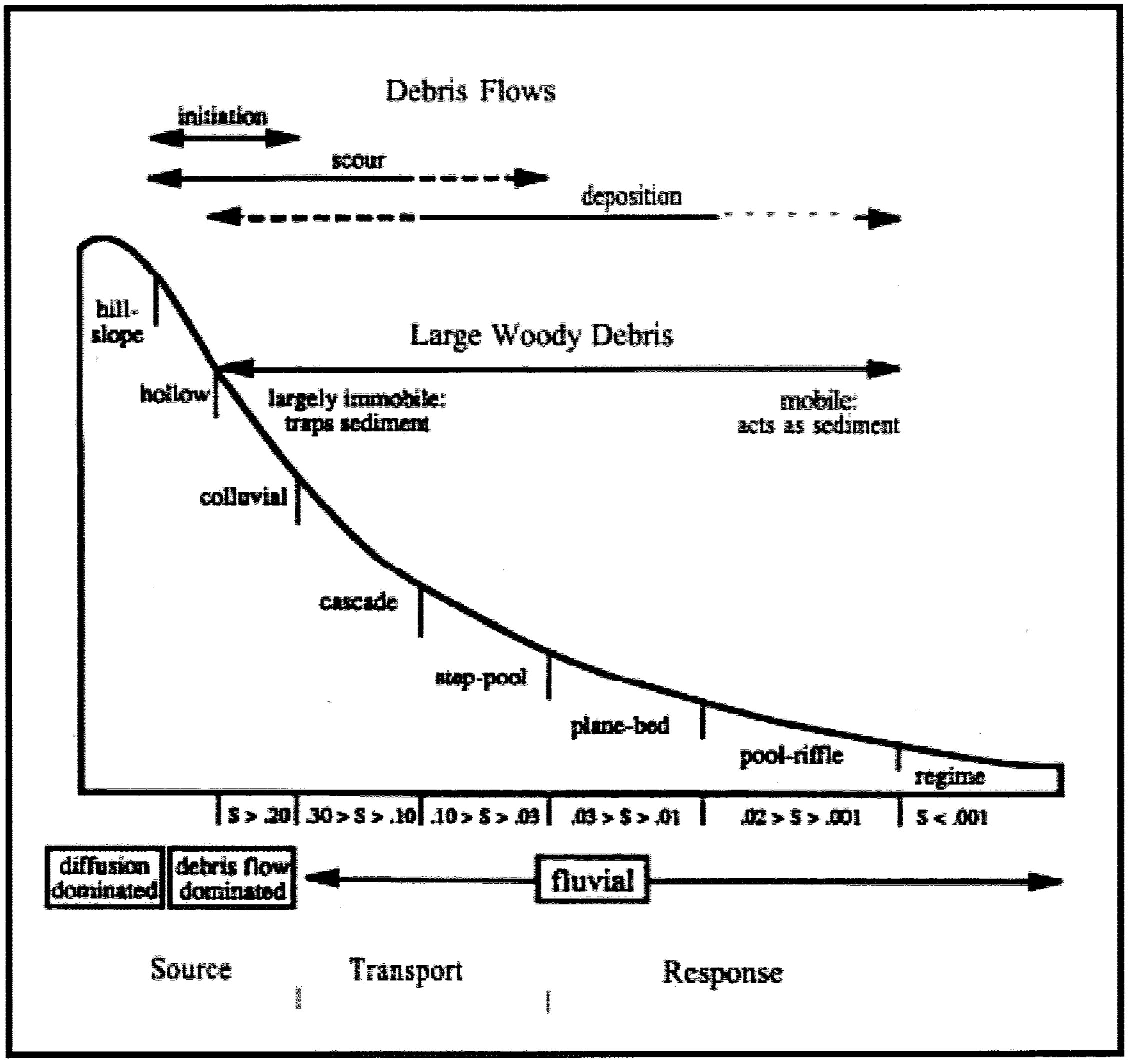
Table 16. Existing and Potential Beneficial Land Uses within the San Francisquito Watershed

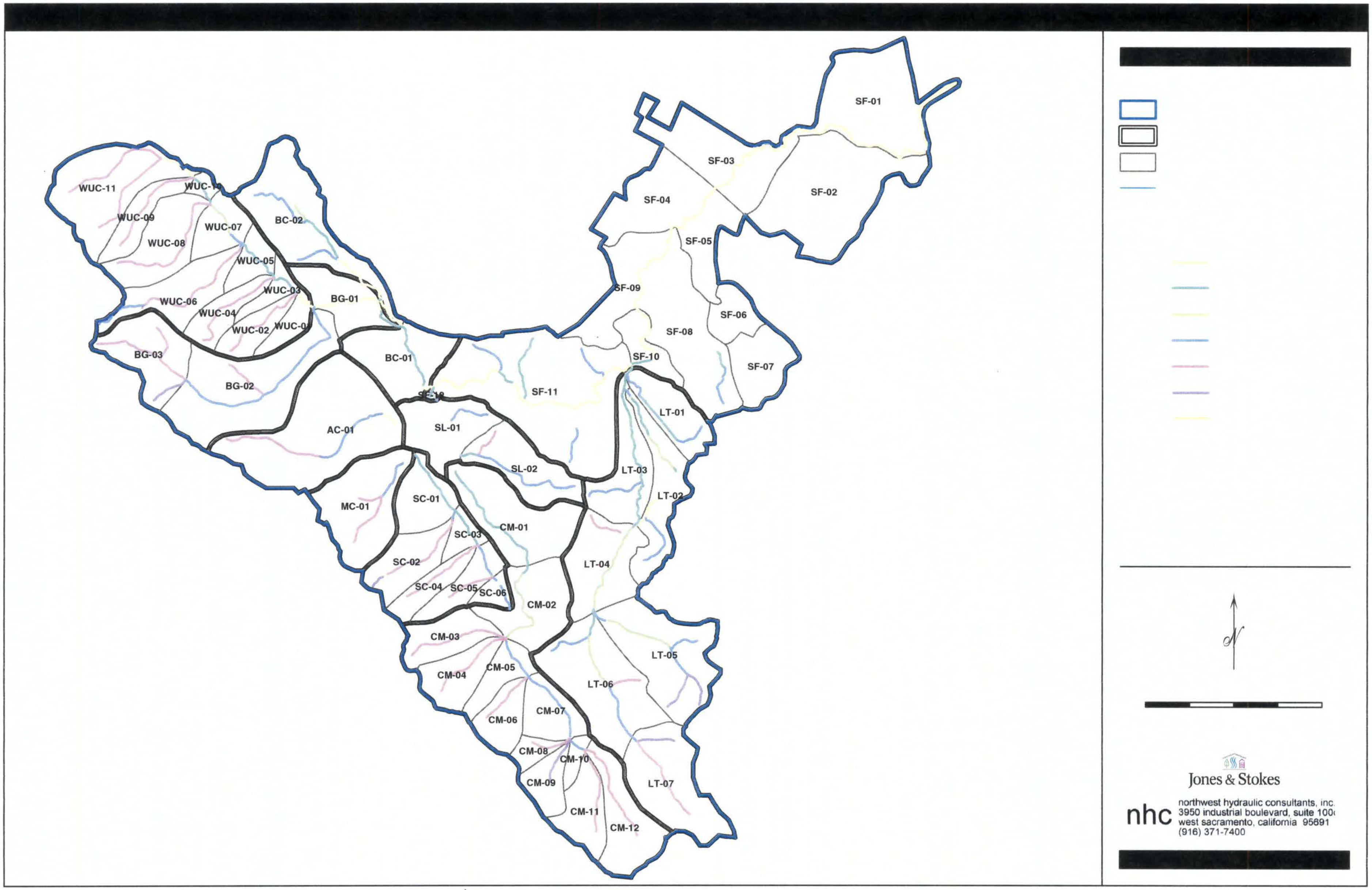
Waterbody	Existing Beneficial Land Uses	Potential Beneficial Land Uses
San Francisquito Creek	Coldwater Freshwater Habitat Fish Migration Fish Spawning Warm Freshwater Habitat Wildlife Species	Water Contact Recreation Non-Contact Water Recreation
Searsville Lake	Agricultural Supply Coldwater Freshwater Habitat Water Contact Recreation Non-Contact Water Recreation Fish Spawning Warm Freshwater Habitat Wildlife Species	
Felt Lake	Agricultural Supply Water Contact Recreation Non-Contact Water Recreation Fish Spawning Warm Freshwater Habitat Wildlife Species	

(Source: Water Quality Plan for the San Francisco Basin (1995))

Figures

Figure 1. Generalized Stream Classification from Montgomery and Buffington (1993)

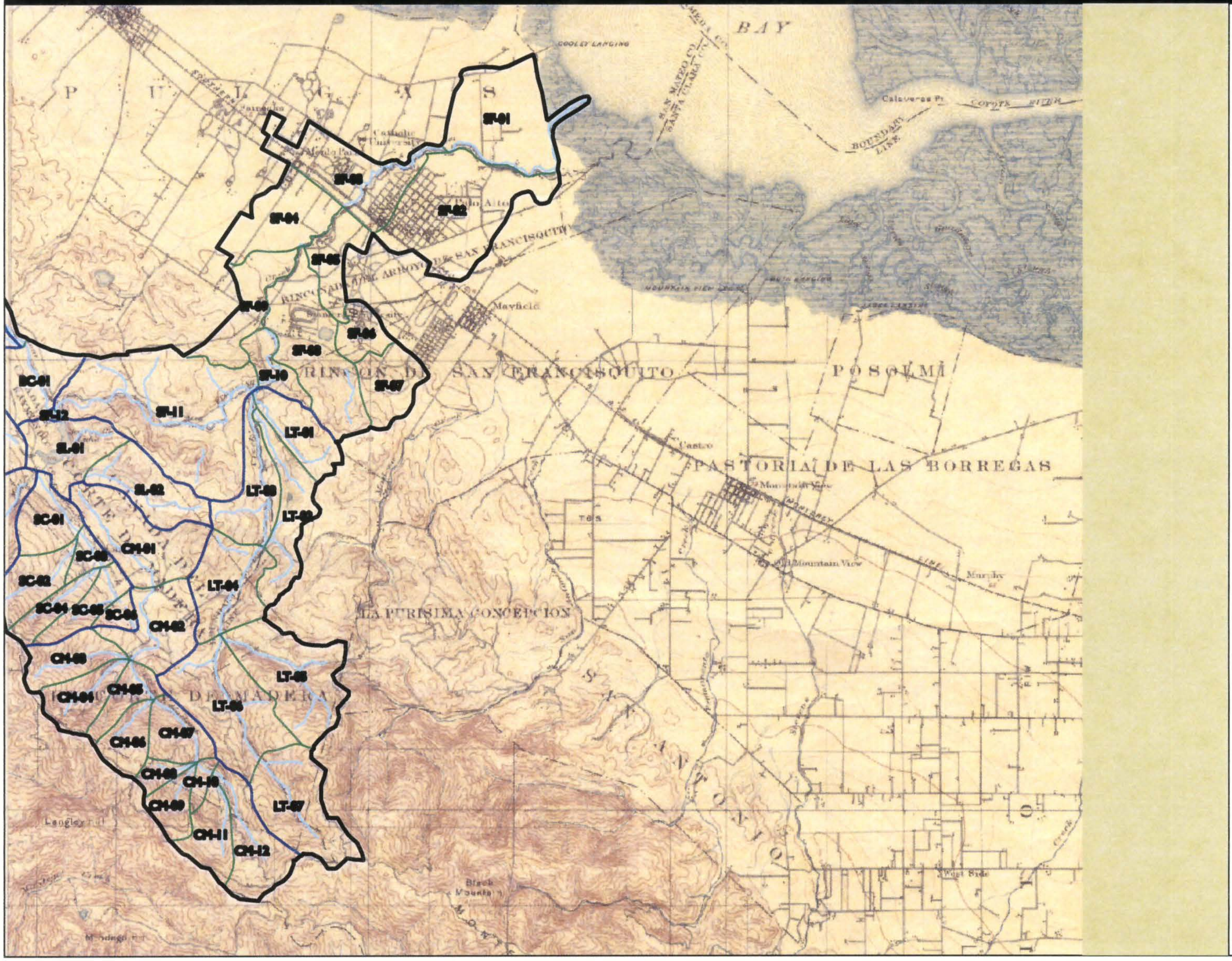




Jones & Stokes

nhc northwest hydraulic consultants, inc.
3950 industrial boulevard, suite 100
west sacramento, california 95691
(916) 371-7400

[redacted]



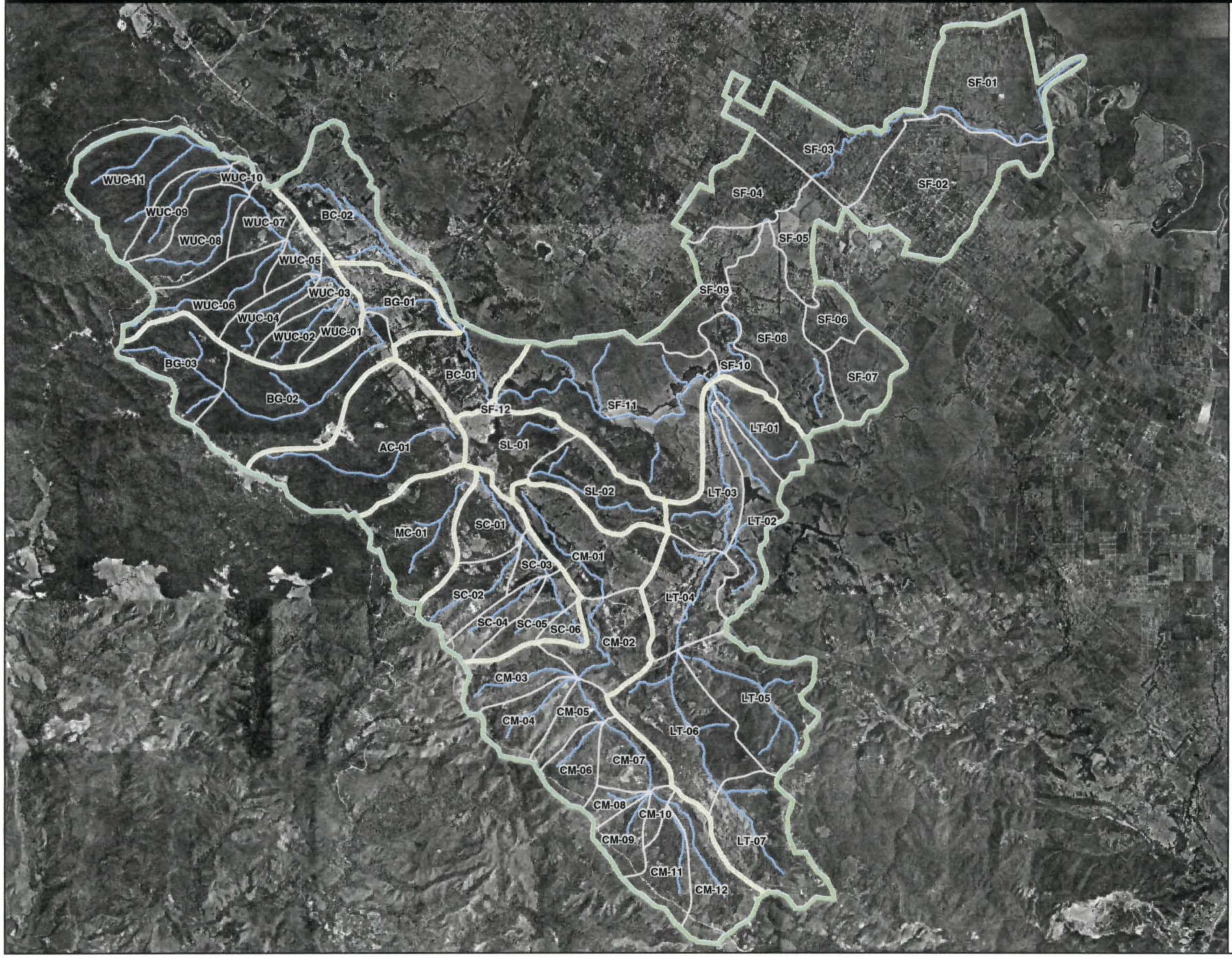
[redacted]

Jones & Stokes

nhc
northwest hydraulic consultants,
3950 industrial boulevard, suite
west sacramento, california 95
(916) 371-7400

[redacted]

[redacted]



[redacted]

🟩

⬜

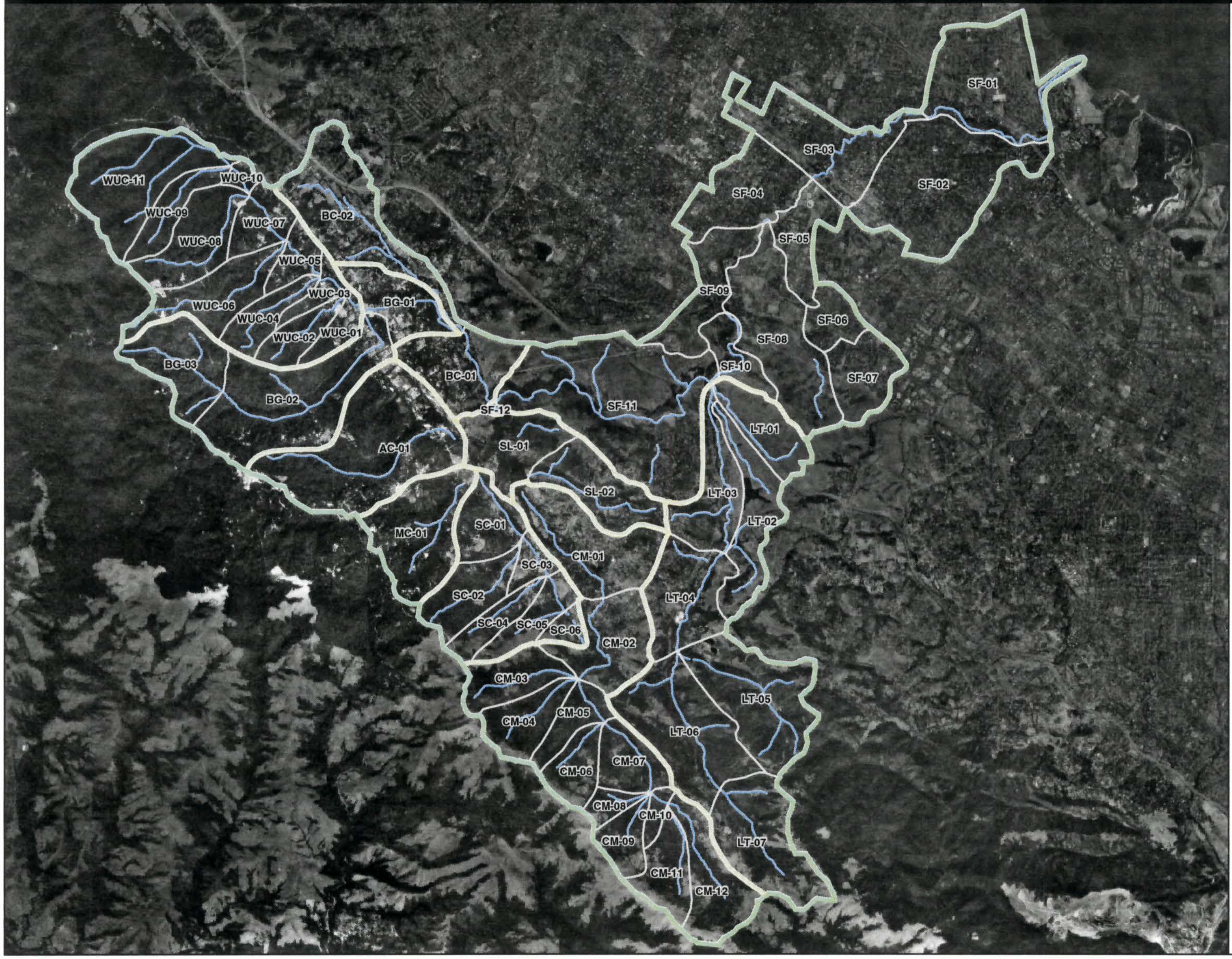
⬜

N

Jones & Stokes

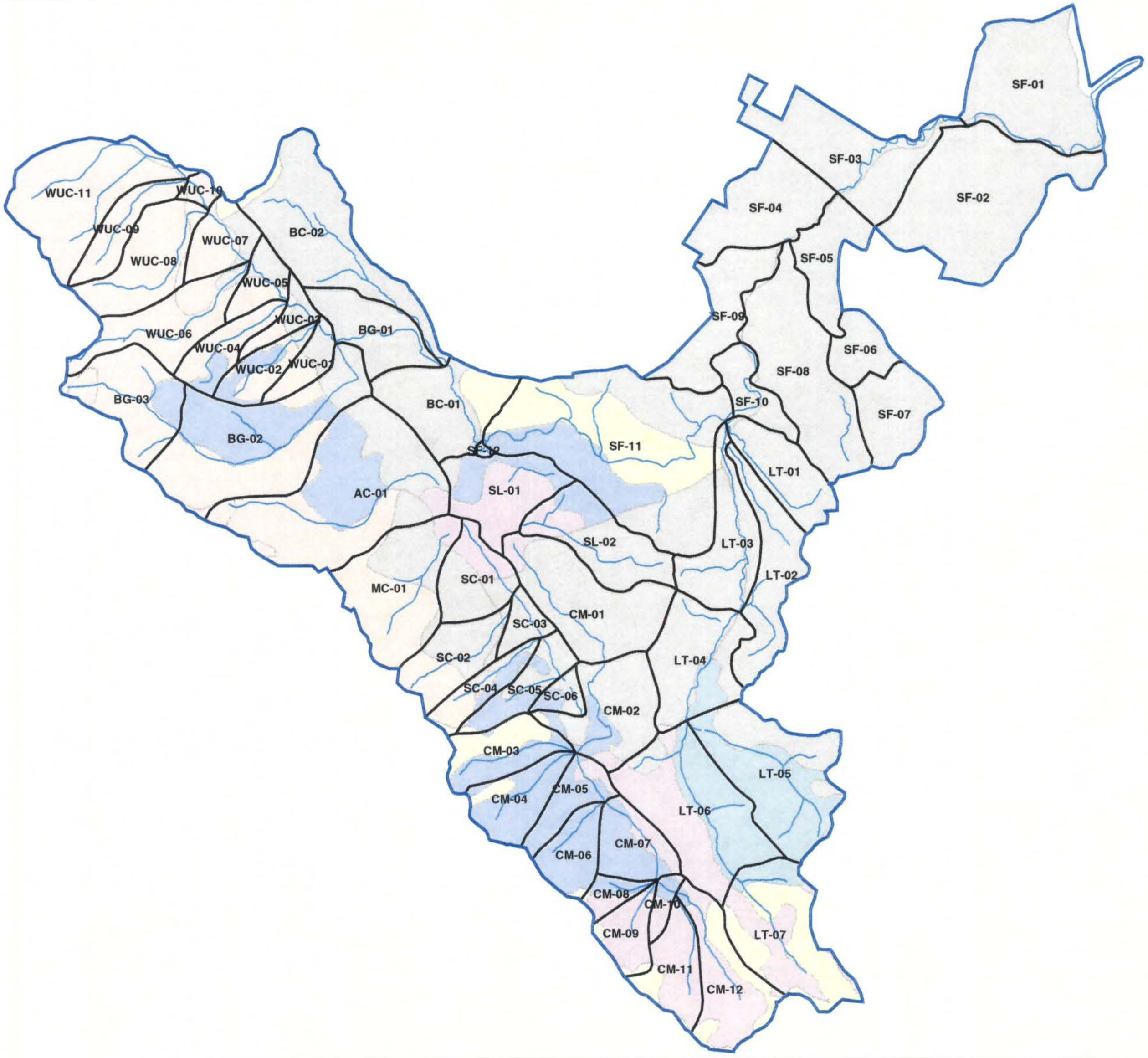
nhc northwest hydraulic consultants, inc
3950 industrial boulevard, suite 100
west sacramento, california 95691
(916) 371-7400

[redacted]



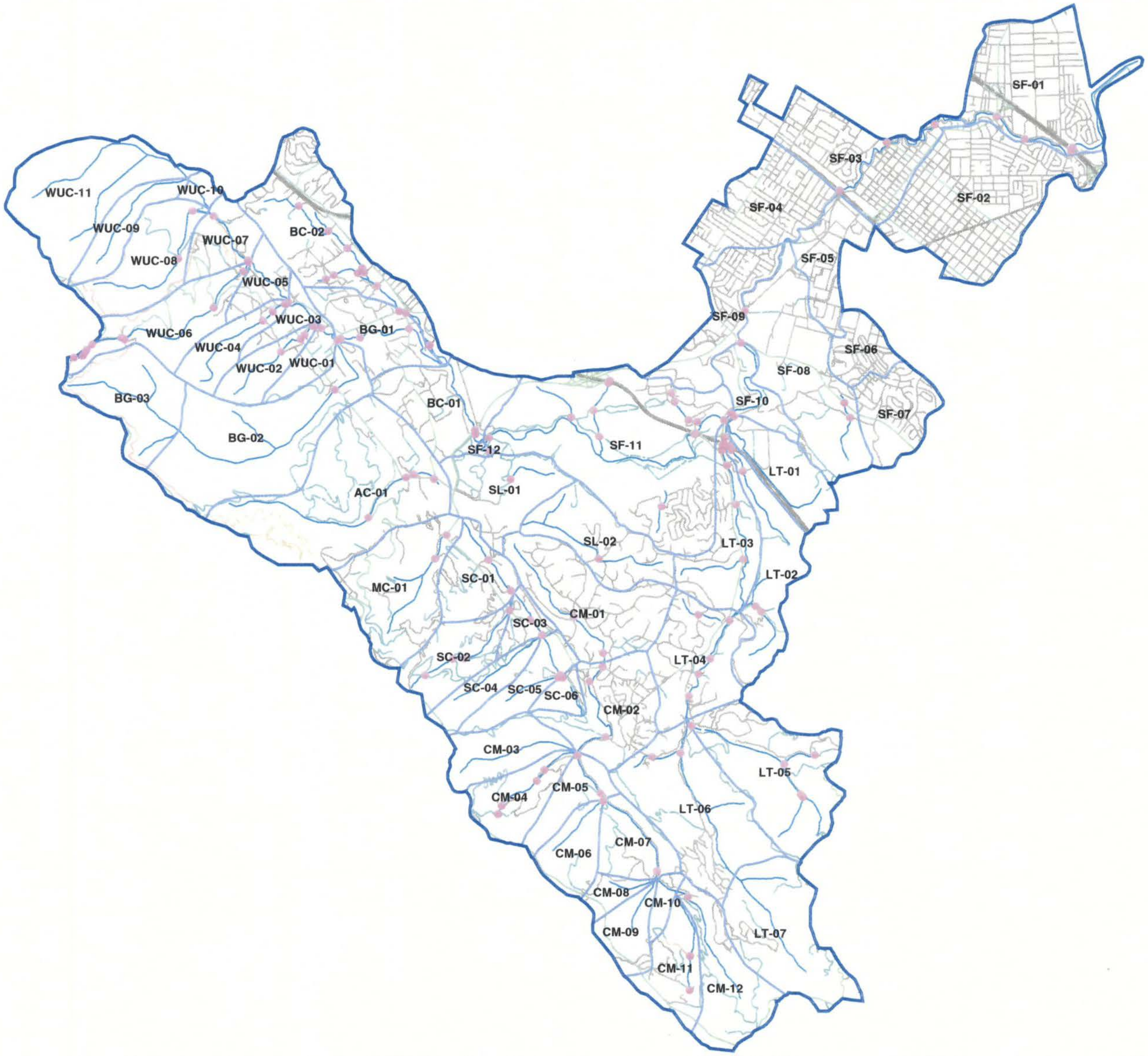
Jones & Stokes

nhc
northwest hydraulic consultants, inc.
3950 industrial boulevard, suite 100c
west sacramento, california 95691
(916) 371-7400



Jones & Stokes

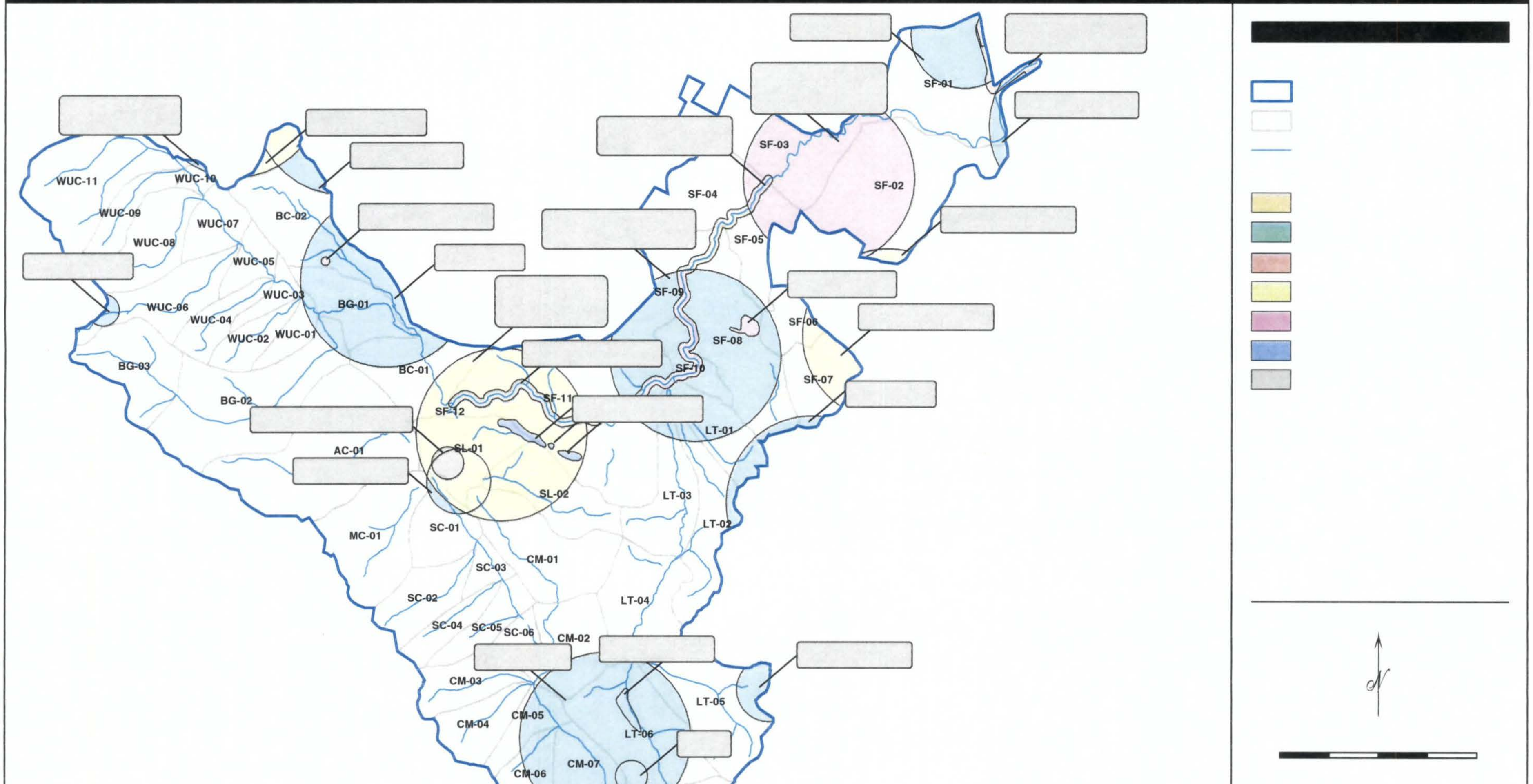
nhc northwest hydraulic consultants, inc.
3950 industrial boulevard, suite 100
west sacramento, california 95691
(916) 371-7400



Jones & Stokes

nhc
northwest hydraulic consultants, inc.
3950 industrial boulevard, suite 100c
west sacramento, california 95691
(916) 371-7400

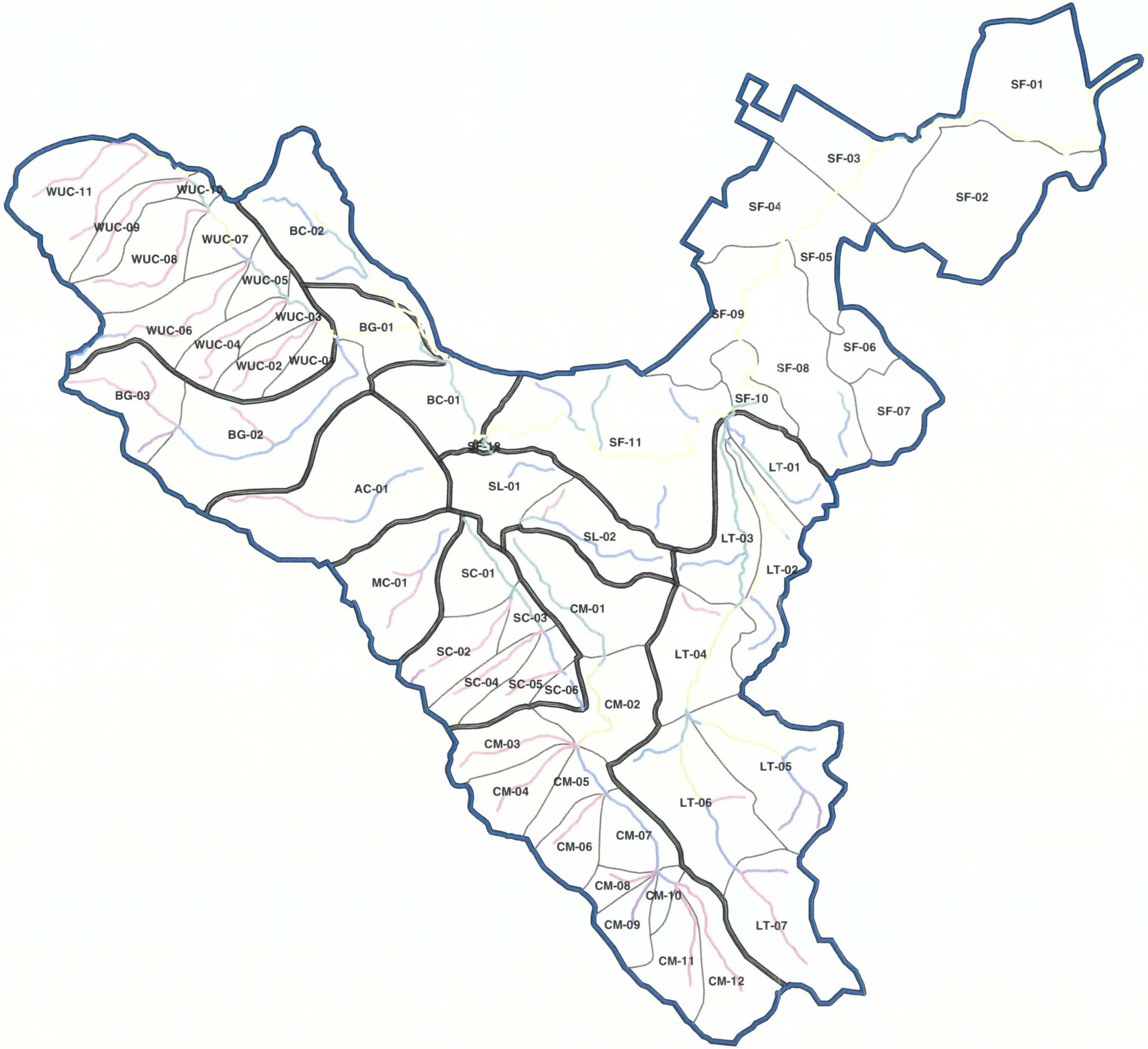
[redacted]



Jones & Stokes

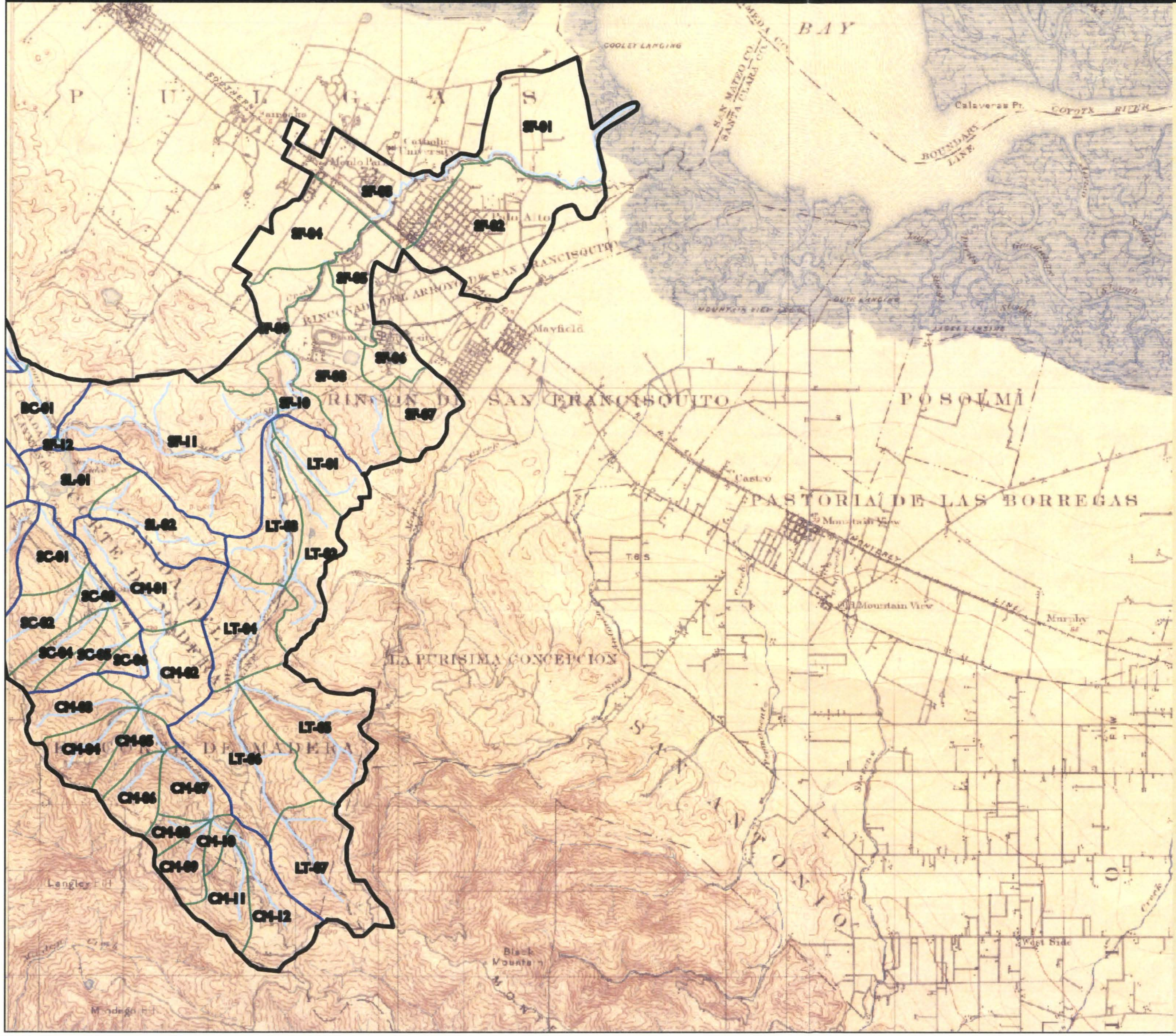
nhc northwest hydraulic consultants, inc.
3950 industrial boulevard, suite 100c
west sacramento, california 95691
(916) 371-7400

[redacted]



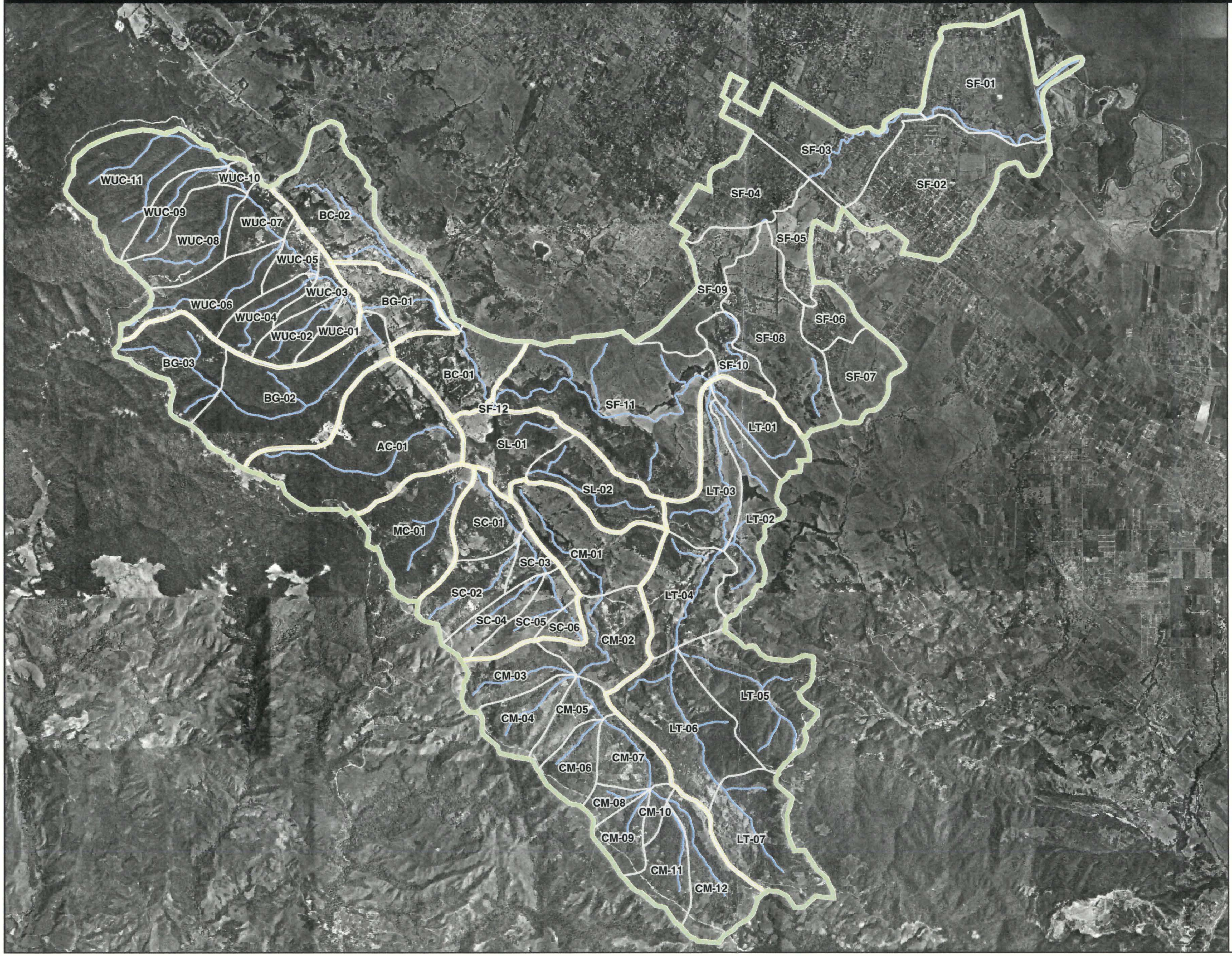
Jones & Stokes

nhc
northwest hydraulic consultants, inc.
3950 industrial boulevard, suite 100
west sacramento, california 95691
(916) 371-7400



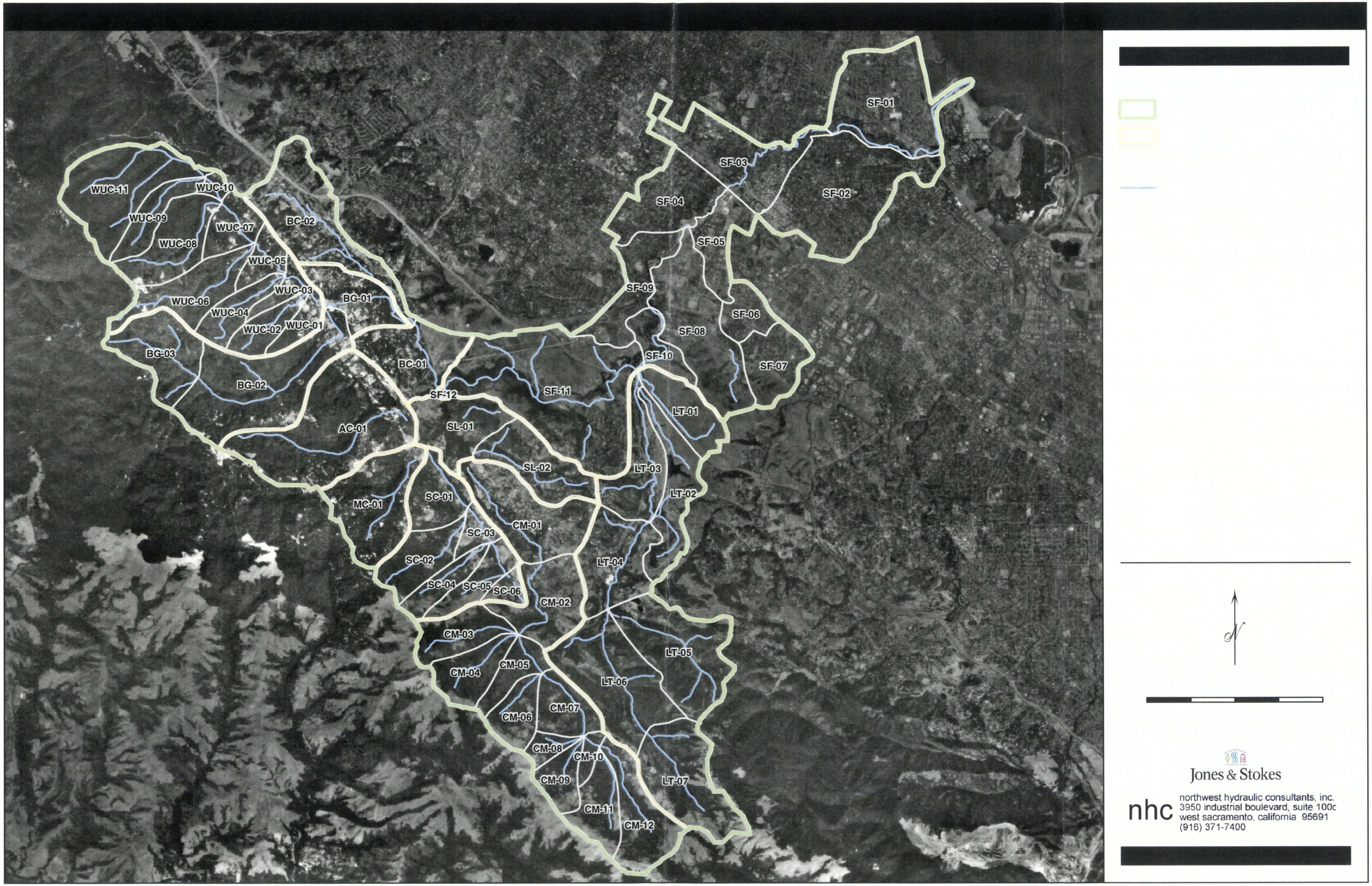
Jones & Stokes

nhc northwest hydraulic consultants,
3950 industrial boulevard, suite
west sacramento, california 956
(916) 371-7400



Jones & Stokes

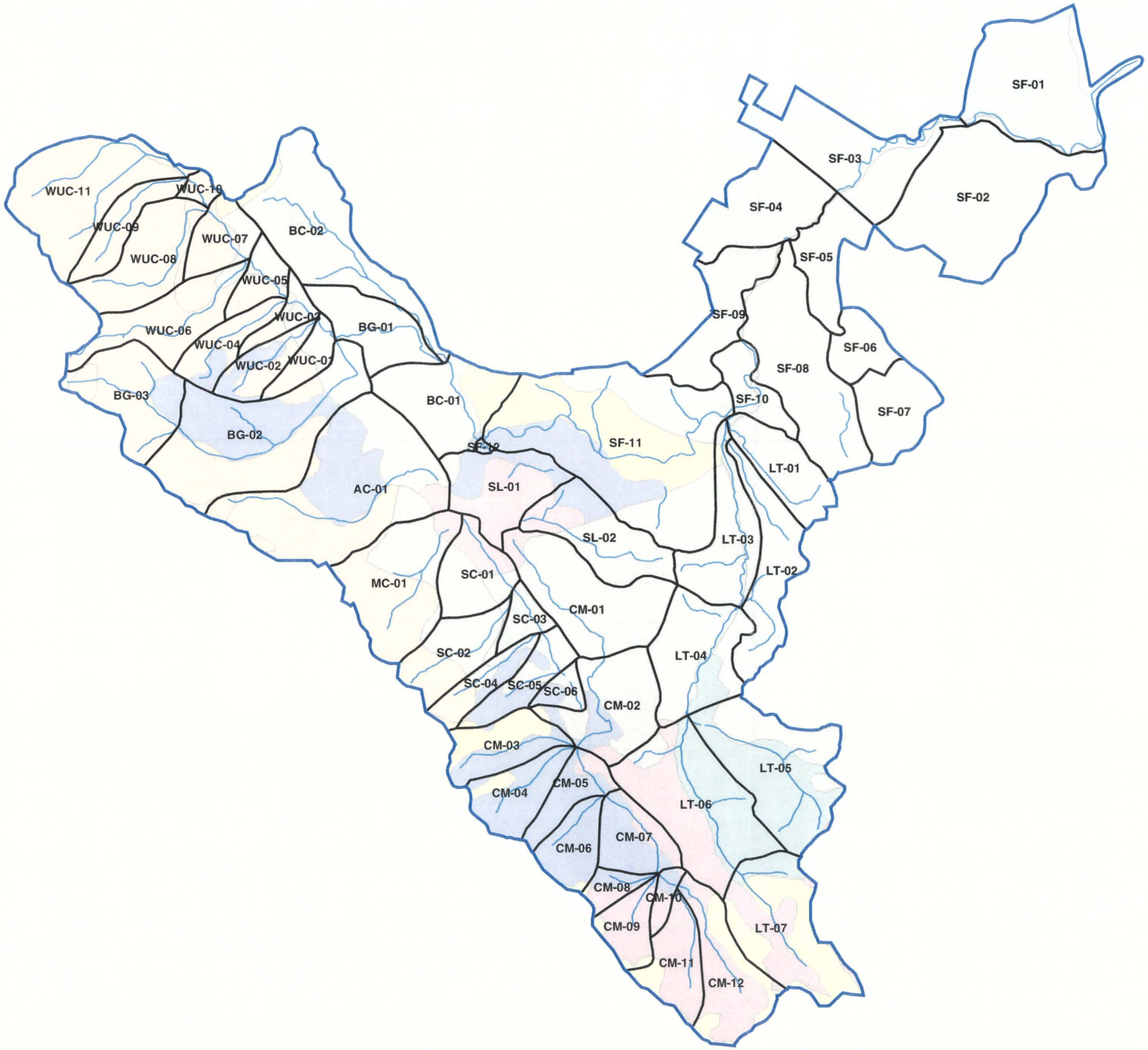
nhc northwest hydraulic consultants, inc
3950 industrial boulevard, suite 100
west sacramento, california 95691
(916) 371-7400



Jones & Stokes

nhc northwest hydraulic consultants, inc.
3950 industrial boulevard, suite 100c
west sacramento, california 95691
(916) 371-7400

[redacted]



[redacted]

▭
▭

🟨
🟦
🟩
🟪
🟧
⬜

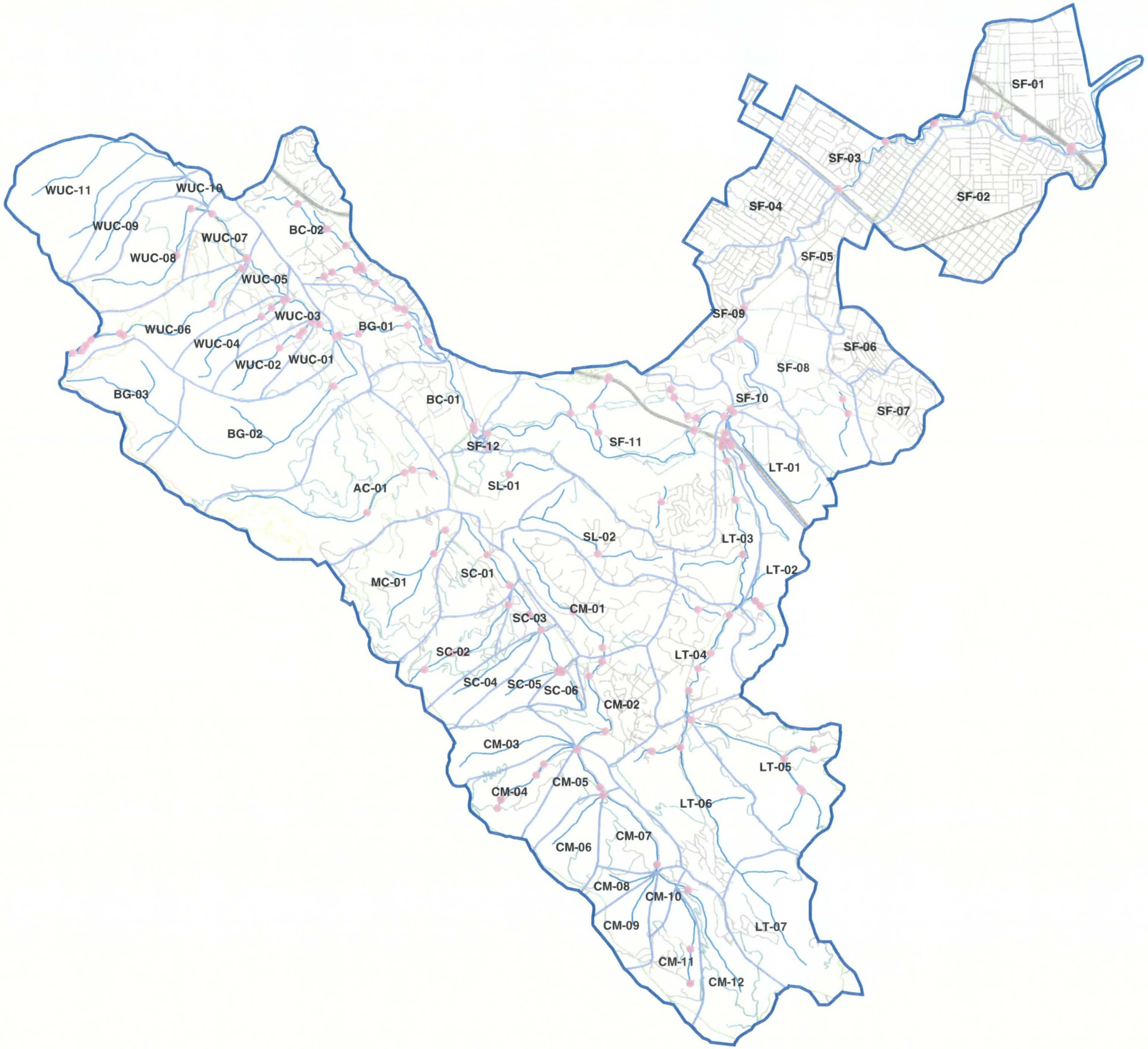
Jones & Stokes

nhc northwest hydraulic consultants, inc.
3950 industrial boulevard, suite 100c
west sacramento, california 95691
(916) 371-7400

[redacted]

[redacted]

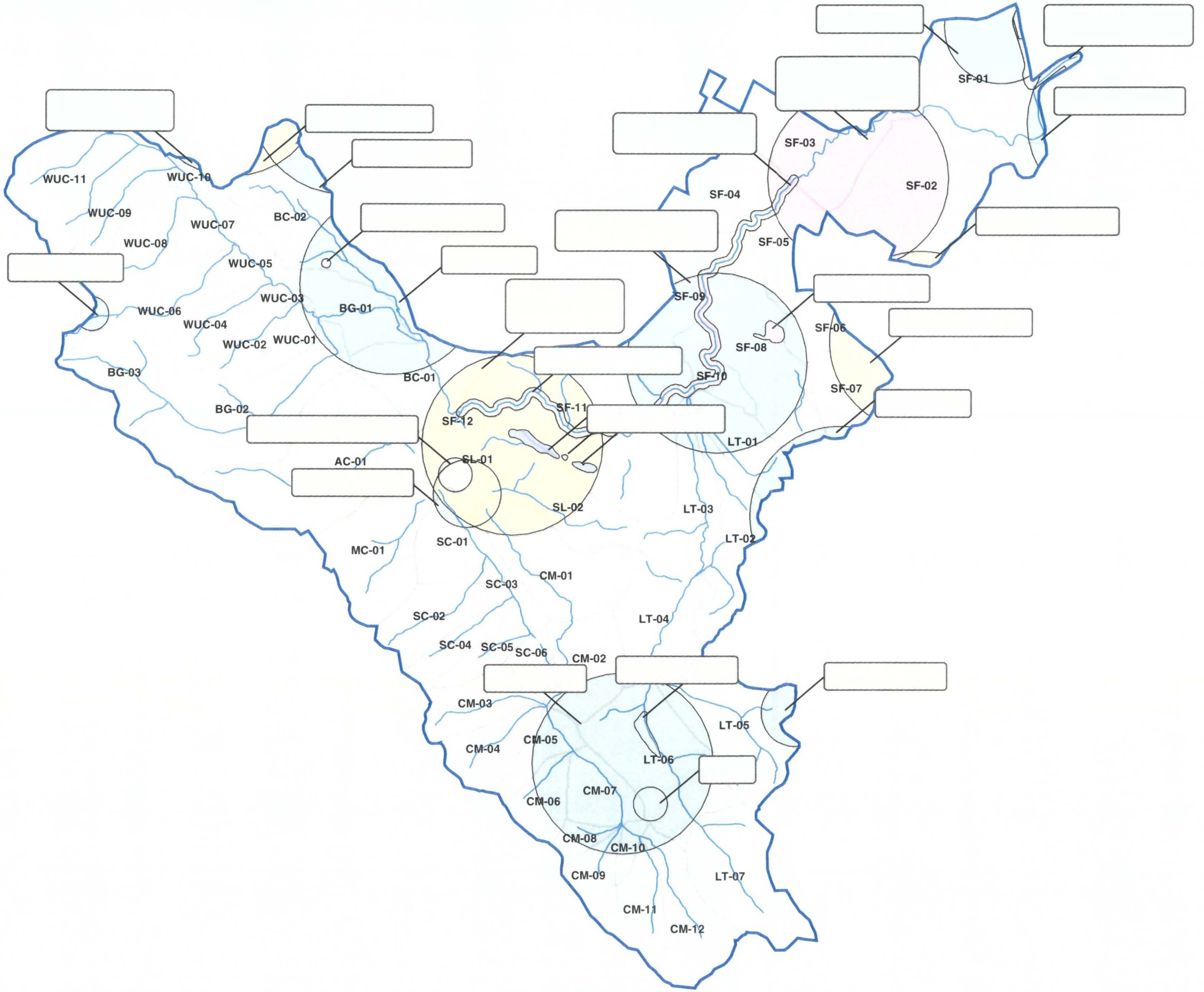
[redacted]

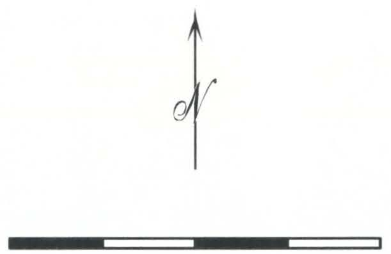


Jones & Stokes

nhc northwest hydraulic consultants, inc.
3950 industrial boulevard, suite 100c
west sacramento, california 95691
(916) 371-7400

[redacted]





Jones & Stokes

nhc
northwest hydraulic consultants, inc.
3950 industrial boulevard, suite 100c
west sacramento, california 95691
(916) 371-7400

Field Protocol

San Francisquito Creek Watershed Analysis And Sediment Reduction Plan

Task 5.3 – Field Plan for Stream Reaches

Approach

The purpose of the field visits is to describe channel morphology for a selection of the stream reaches in the San Francisquito Creek Watershed, as described in the following section. We plan to visit one or two sites in each of the selected reaches and describe channel morphology on the attached field form.

In addition to the channel morphologic measurements on the form, we also plan measurements of substrate at those sites where others have completed sediment transport estimates, collecting the following measurements:

- Wolman pebble counts
- Estimates of percentage of sand in surface layer of substrate (visual)
- Measurements of pool volumes filled by bed material load

Substrate measurements are planned for sites near the stream and sediment gages near the mouths of Bear, Los Trancos and Corte Madera Creeks.

Measurement Sites

The Existing Conditions Report and the Watershed Sediment Analysis Report provide a reach breakdown of the streams in the San Francisquito Creek watershed, following the Montgomery-Buffington classification system applied at the sub-subwatershed level (attached). We plan to visit a selection of the pool-riffle, pool-riffle plane bed, plane bed and step-pool reaches in Corte Madera, Los Trancos and Bear Watersheds.

The table on the following page summarizes the proposed field visit sites, dates of visits, and the planned measurements at the site. Note that no field visits are planned for lower San Francisquito Creek as it has been adequately described in past reports.

Five of the sites that are planned for a visit are on Stanford Lands. An access agreement to visit these sites will be submitted the week of July 28th. We anticipate field visits in the week of August 18th, allowing time for processing and then submission of notification to Stanford.

Table 1: Summary of Planned Stream Reach Site Visits

Stream	***Reach***	***Date***	***Measurements***	
			Channel	***Substrate***
Upper Corte Madera	Step pool reach in CM-10, CM-7, CM-5	June 3	Yes	No
Corte Madera	Plane bed reach in CM-2 near Willowbrook Drive	June 3	Yes	No
Corte Madera	Pool-riffle reach in CM-01 at Westridge Road gage	Week of August 18	Yes	Yes
Los Trancos	Plane bed reach in LT-04, near Los Trancos Road	Week of August 18	Yes	No
Los Trancos	Pool riffle/plane bed reach in LT-03 at Arastradero Road stream gage	Week of August 18	Yes	Yes
Los Trancos (Stanford)	Pool riffle plane bed reach at San Francisquito Creek	Week of August 18	Yes	No
Bear Creek (Stanford)	Pool riffle plane bed reach at Sand Hill Road	Week of August 18	Yes	Yes
Bear Gulch	Step pool reach at Woodside Road	Week of August 18	Yes	No
West Union Creek	Pool riffle plane bed reach at Woodside Road	Week of August 18	Yes	No
San Francisquito Creek (Stanford)	Pool-riffle reach at mouth of Bear Creek	Week of August 18	Yes	No
San Francisquito Creek (Stanford)	Pool-riffle reach at mouth of Los Trancos Creek	Week of August 18	Yes	No
San Francisquito Creek (Stanford)	Pool-riffle reach at Webb Ranch	Week of August 18	Yes	No

San Francisquito Creek Watershed Study
River Morphology Assessment Form

Observers Initials ______ Date ______________ Time: ____:____
Site #: _________ Subwatershed _________________ Subsubwatershed _________
Site Location: ____
Adjacent land use: ____

Floodplain Characteristics:
Clearly defined floodplain? Y / N RB________________________LB________________________

Floodplain Features:
- ☐ Abandoned channels
- ☐ Meander Scars
- ☐ Swales
- ☐ Recent overbank deposition
- ☐ Other _______________________
- ☐ High Water Marks _______________
- Terraces / Benches _______________

Channel Characteristics:
Channel Planform (description)____________________
Approximate Width (bankfull) _______
Approximate Depth (bankfull) _______
Channel Entrenched Y / N (depth:_______)
Bed Material Description ______________________
Observed bedforms_____________________________
Headcut Y / N (depth_____)

Flow Conditions:
water in channel? Y / N Water depth: ______ Flow Conditions: Flowing / Stagnant

Bed Controls:
- ☐ none
- ☐ solid bedrock
- ☐ weathered bedrock
- ☐ boulders
- ☐ gravel armour
- ☐ cohesive materials
- ☐ bridge protection
- ☐ grade control structures
- ☐ other____________________

Width Controls:
- ☐ none
- ☐ bedrock
- ☐ boulders
- ☐ gravel armour
- ☐ revetments
- ☐ cohesive materials
- ☐ bridge abutments
- ☐ dykes or groynes
- ☐ other____________________

Bank Characteristics:

Left Bank
Height _________
Material _____________
Observed stratification _____________
Slope (gradual, moderate, steep, nearly vertical)
Vegetation cover __________________

Right Bank
Height _________
Material _____________
Observed stratification _____________
Slope (gradual, moderate, steep, nearly vertical)
Vegetation cover __________________

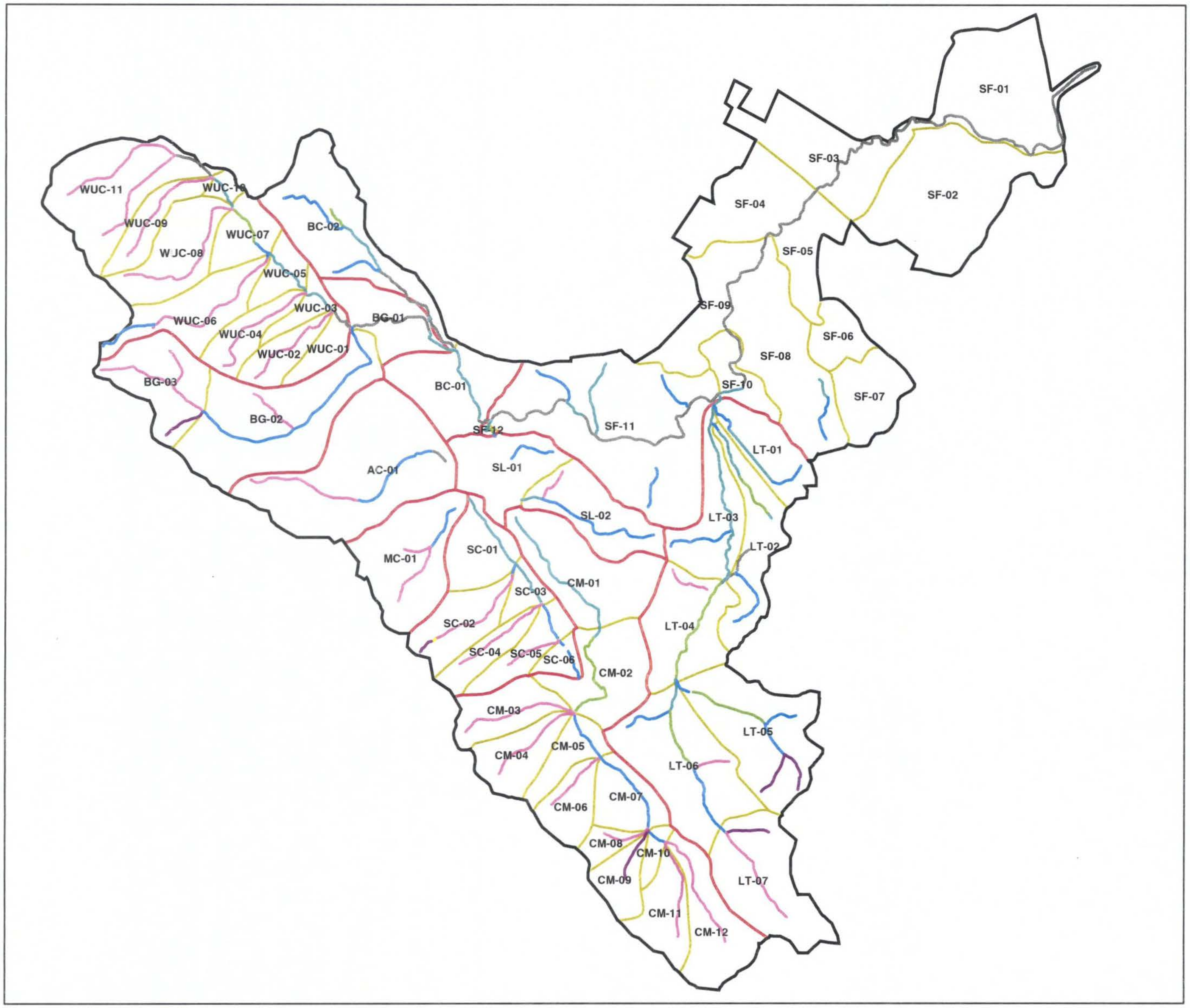
Bank Erosion Features:

Left Bank
Landslide (length of bank______ depth_____)
Debris Flow (length of bank_____depth_____)
Earth Flow (length of bank_____depth_____)
Soil Creep ____________________________
Stream bank erosion
length_____height_____depth_____failure type:_________

Right Bank
Landslide (length of bank______ depth_____)
Debris Flow (length of bank_____depth_____)
Earth Flow (length of bank_____depth_____)
Soil Creep ____________________________
Stream bank erosion
length_____ height_____depth_____failure type:_________

Sediment Storage Features:
Instream bars (type: ______________________________________ size: _______________)
Instream islands (desc/size: ____)
Instream aggradation (material type:___________________________approx. depth: _________)

Notes:



Legend

Slope (%)	Stream Type
<=1	Pool - Riffle
1-2	Pool - Riffle / Plane Bed
2-3	Plane - Bed
3-10	Step - Pool
10-20	Cascade
20-30	Cascade / Colluvial
>30	Colluvial

CM-03 Sub-Sub-Watershed Label

▭ Sub-Sub-Watershed Boundary

▭ Sub-Watershed Boundary

▭ Watershed Boundary

Strean Slope Calculations are based on Stream Segments Varying in Length Between a Range of 14 Meters to 2600 Meters.

N

0 3,000 6,000 9,000 12,000 Feet

Scale : 1 inch = 6000'

Channel Types using the Montgomery - Buffington Classification

nhc northwest hydraulic consultants, inc.
3950 industrial boulevard, suite 100c
west sacramento, california 95691
(916) 371-7400

Jones & Stokes

N: / NHC / 03003.03 / ARCMAP / STREAM_SLOPE_M2_NEW.MXD

JULY 10, 2003

Sediment Analysis

anta Clara Valley
Vater District

5750 ALMADEN EXPWY
SAN JOSE, CA 95118-3686
TELEPHONE (408) 265-2600
FACSIMILE (408) 266-0271
www.valleywater.org
AN EQUAL OPPORTUNITY EMPLOYER

December 15, 2003

Mr. Dale Bowyer
San Francisco Bay Region
Regional Water Quality Control Board
1515 Clay Street, Suite 1400
Oakland, CA 94612

Subject: San Francisquito Creek Watershed Sediment Analysis Final Report

Dear Mr. Bowyer,

I am pleased to submit the enclosed *San Francisquito Creek Watershed Sediment Analysis Final Report (Proposition 13 Grant Project Task 5)*. This report is the work product for the *San Francisquito Creek Watershed Sediment Assessment Workplan* (revised June 2003) *Task 4*. The workplan fulfills the Santa Clara Valley Urban Runoff Pollution Prevention Program (SCVURPPP) Permit Provision 9(f) (*i*) of Order 01-024 of the Regional Water Quality Control Board's (RWQCB) adopted on February 21, 2001, and fulfills the San Mateo Countywide Stormwater Pollution Prevention Program (SM-STOPPP) Permit Provision C. 10 of Order 99-059 of the RWQCB's adopted on July 21,1999, for implementation of the watershed sediment assessment and analysis for San Francisquito Creek. Also, attached is the rapid sediment budget field protocol titled *Field Plan for Stream Reaches(Prop 13 Grant Project Task 5.3)*.

The report is submitted jointly by the co-permittees of the two Programs (SCVURPPP and SM-STOPPP) in the San Francisquito Creek watershed in order to provide a coordinated and cooperative effort by the two programs; these agencies include the following: County of San Mateo, City of East Palo Alto, City of Menlo Park, City of Portola Valley, City of Woodside, County of Santa Clara, City of Palo Alto, and Santa Clara Valley Water District. In addition, several agencies have also greatly contributed to the implementation of the project, especially the San Francisquito Creek Joint Powers Authority, who is serving as the Prop 13 Grant Administrator and Project Manager, under which this effort is undertaken. Other participating agencies include the United States Geological Survey, Stanford University, the San Francisquito Creek Watershed Council, and CLEAN Southbay. We wish to thank these agencies for their continued participation in this coordinated effort and assistance in developing this report.

If your have any questions concerning this matter, please contact me at (408) 265-2607, extension 2928, or email at RNarsim@valleywater.org .

Sincerely,

Roger Narsim
Engineering Unit Manager
Countywide Watershed Programs Unit
Santa Clara Valley Water District

Enclosure (1): Sediment Analysis Report, November 2003
Attachment: Field Plan for Stream Reaches
Express Delivered on December 15, 2003
cc: Adam Olivieri (EOA), Program Manager, SCVURPPP
Robert M. Davidson, Program Coordinator, SM-STOPPP
SCVURPPP Co-permittees (see attached distribution list)
SM-STOPPP Co-permittees (see attached distribution list)
lcy:lcy
sedbudgetanalysis.121503.SCVWDlet
bcc: D. Chesterman, B. Goldie, R. Narsim, B. Calhoun, Distribution List

SCVURPPP Co-Permittees

Laura Young
Santa Clara Valley Water District

Phil Bobel
City of Palo Alto

Joe Teresi
City of Palo Alto

Steve Homan
County of Santa Clara

SM-STOPPP Co-Permittees

Mark Chow
County of San Mateo

Debra O'Leary
City of East Palo Alto

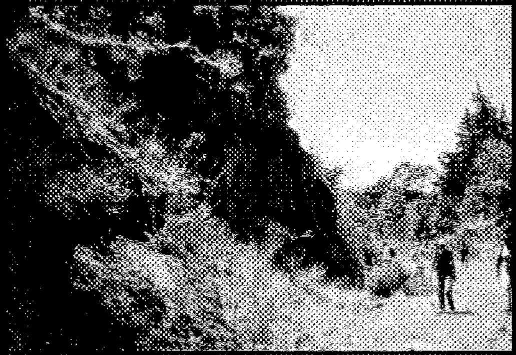
Dianne Dryer
City of Menlo Park

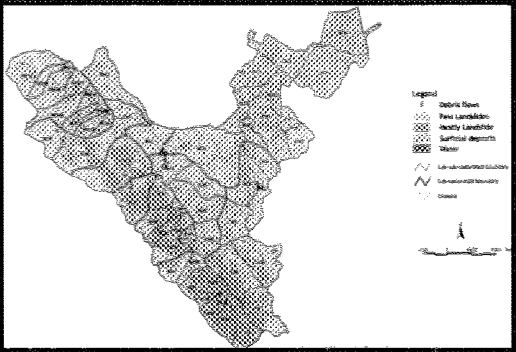
Leslie Lambert
City of Portola Valley

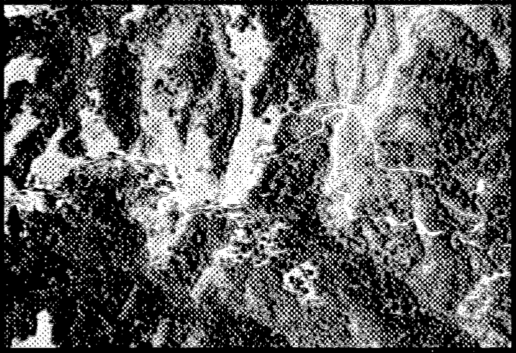
Kent Dewell
City of Woodside

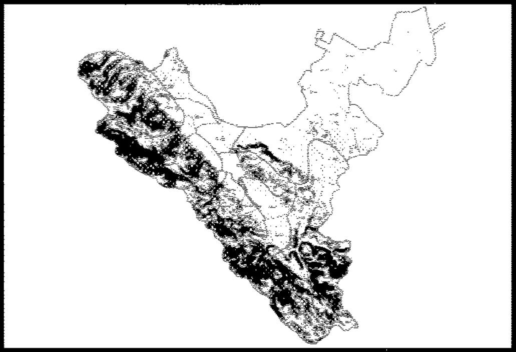
San Francisquito Creek Watershed Sediment Analysis

FINAL REPORT









November 2003

Prepared for:

San Francisquito Creek
Joint Powers Authority

Prepared by:

nhc northwest hydraulic consultants
Leaders in water resource technology

Jones & Stokes

San Francisquito Creek
Watershed Analysis and Sediment Reduction Plan

Task 5
Watershed Sediment Analysis

Final Report
November 2003

Prepared for:
San Francisquito Creek
Joint Powers Authority

Prepared by:
Northwest Hydraulic Consultants
3950 Industrial Boulevard, Suite 100c
West Sacramento, CA 95691
Contact: Ken Rood
(916) 371-7400

Jones & Stokes Associates
2880 Zanker Road, Suite 210
San Jose, CA 95134

EXECUTIVE SUMMARY

The objective of the Watershed Sediment Analysis was to develop a rapid sediment budget for San Francisquito Watershed that describes the processes that deliver sediment from slopes to streams, the rates of transport through streams, and the contribution of human activities to erosion and transport. The watershed was divided into four groups of subwatersheds – Searsville Lake, Los Trancos, Bear, and San Francisquito Creek. Each grouping had sediment transport or deposition measurements at its outlet that allowed verification of the erosion estimates or calculation of a balance to estimate missing erosion components.

Different approaches were taken to construction of each of the budgets because of the nature of the available information on erosion processes and rates and the nature of the erosion processes in each group of subwatersheds. Budgets were constructed for 1995 to 2000 and for long-term or average conditions. For 1995 to 2000, the most detailed information on erosion and transport were from Searsville Lake watershed. Los Trancos had less information on rates of erosion; Bear subwatershed had uncertainties in sediment transport and little information on rates of erosion. Records of deposition in Searsville Lake and other sediment transport measures suggest that erosion and transport were unusually large from 1995 to 2000.

We also constructed long-term budgets in Searsville Lake, Los Trancos and Bear by adjusting the short-term erosion measurements to match long-term sediment transport. These budgets are less accurate than the short-term ones. A long-term budget was also prepared for San Francisquito watershed. While consider detail is available on transport and deposition of sediment along San Francisquito Creek, unfortunately, there is little or no information on bank erosion along San Francisquito Creek or erosion from urban areas, two key elements of the sediment contribution from this subwatershed.

A detailed sediment budget for the Searsville Watershed for 1995 to 2000 period shows that nearly all the erosion occurred in Corte Madera Creek, much less erosion occurred in Alambique, Martin and Sausal Creeks. About half of the erosion in Corte Madera Creek was from two sub-subwatersheds in upper Corte Madera Creek. Streamside landslides, which were partly initiated by incision and channel shifting, and shallow landslides on slopes were the greatest contributors to the total erosion. Streambank erosion and surface erosion were insignificant to total erosion from 1995 to 2000. The human-related component of erosion was about 16% of the total, primarily from landslides initiating at roads or in developments.

Long-term average annual sediment deposition in Searsville Lake is less than 40% of that from 1995 to 2000 and different processes seem to dominate the long-term budget. Landsliding on lower valley walls – which seems to be associated with extreme floods – is a far less important component. Erosion is dominated by shallow landslides from slopes which occur abundantly every five years or so. Landslides that are initiated by road construction or drainage diversion are also an important part of the human-related erosion. Chronic sediment sources, such as surface erosion from unpaved and paved roads and gully erosion become significant components of the sediment budget. The human-related component of erosion is greater in the long-term than from 1995 to 2000 because of the greater role of surface erosion and bank erosion.

Both 1995 to 2000 and long-term erosion in Los Trancos and Bear watersheds are very much lower than from Searsville Lake. The greatest contributions in these watersheds are from steep tributaries that extend into the Santa Cruz Mountains. Much less significant erosion occurs along the main valley bottom in the San Andreas Fault Zone.

Los Trancos has the least erosion of the three watersheds in the Santa Cruz Mountains. Shallow landsliding dominates the short and long-term budget in Los Trancos Creek. Landslides also dominate human-related erosion and this erosion is a significant portion of the total. Bear watershed is dominated by bank erosion from 1995 to 2000 and by shallow landslides and bank erosion in the long-term. Human-related erosion is mostly restricted to bank modifications through Woodside and gully erosion from development and is a small portion of the total.

Sediment from Searsville Lake watershed is deposited in Searsville Lake and only some of its fine sediment is carried over the dam to San Francisquito Creek. Consequently, the existing budget for the whole watershed is from Los Trancos, Bear and the San Francisquito subwatershed. Bank erosion along San Francisquito Creek and erosion in the tributaries in the upper half of the subwatershed seem to be important components of the overall budget. Unfortunately, their contribution is not accurately known. However, the overall contribution from the San Francisquito subwatershed may be about the same as from Bear subwatershed.

Construction of Searsville Dam has greatly reduced the long-term sediment transport through San Francisquito Creek, to about one-third of its natural value. It is our view that the reduction of coarse sediment supply from Searsville Watershed has contributed to the observed changes along San Francisquito Creek. Slope adjustments in response to the lowered sediment transport are thought to have caused the incision on the upper part of the alluvial apron and the deposition along the lower course of San Francisquito Creek. Other likely stream impacts include coarsening of the streambed in the upper creek, leading to formation of a stable pavement of coarse cobbles and boulders.

TABLE OF CONTENTS

LIST OF TABLES IV
LIST OF FIGURES V
LIST OF APPENDICES V

1. INTRODUCTION 1

2. THE SAN FRANCISQUITO WATERSHED 3

2.1. PHYSIOGRAPHY AND GEOLOGY 3
2.2. CONCEPTUAL MODELS OF EROSION, TRANSPORT AND DEPOSITION 4
2.3. DEFINING SEDIMENT TRANSPORT 5

3. HYDROLOGY 7

3.1. STREAM GAUGING RECORDS 7
3.2. CLIMATE AND HYDROLOGY 7
3.3. DEVELOPMENT AND HYDROLOGY 8

4. SEARSVILLE LAKE SEDIMENT BUDGET 12

4.1. APPROACH 12
4.2 SEDIMENT TRANSPORT TO SEARSVILLE LAKE 12
4.3. SEDIMENT SOURCES 13
4.4 HUMAN CONTRIBUTIONS TO EROSION 20
4.5. CORTE MADERA CREEK 21
4.6. SEDIMENT BUDGET 1995 TO 2000 23
4.7. LONGER-TERM SEDIMENT BUDGETS 25

5. LOS TRANCOS SEDIMENT BUDGET 28

5.1. APPROACH 28
5.2. SEDIMENT TRANSPORT 28
5.3. SEDIMENT SOURCES 29
4.4. HUMAN CONTRIBUTIONS TO EROSION 30
5.5. LOS TRANCOS CREEK 32
5.6. SEDIMENT BUDGET FROM 1995 TO 2000 32
5.6. LONGER-TERM SEDIMENT BUDGETS 33

6. BEAR SEDIMENT BUDGET 35

6.1. APPROACH 35
6.2. SEDIMENT TRANSPORT 35
6.3. SEDIMENT SOURCES 36
6.4 HUMAN CONTRIBUTIONS TO EROSION 37
6.5. BEAR, BEAR GULCH AND WEST UNION CREEKS 39
6.6. SEDIMENT BUDGET FROM 1995 TO 2000 39
6.6. LONGER-TERM SEDIMENT BUDGETS 41

7. SAN FRANCISQUITO CREEK SEDIMENT BUDGET 43
7.1. BACKGROUND 43
6.3. SEDIMENT TRANSPORT 43
7.3. SEDIMENT SOURCES 44
7.4. HUMAN CONTRIBUTIONS TO EROSION 48
7.5. SAN FRANCISQUITO CREEK 49
7.6. SEDIMENT BUDGET 1964 TO 1998 50
7.7. BUDGET WITHOUT SEARSVILLE DAM 51
8. SUMMARY AND CONCLUSIONS 53
9. REFERENCES 56

List of Tables

3-1 USGS Stream Gages on San Francisquito Creek and Tributaries
3-2 Total Impervious Cover and Road Densities for San Francisquito Subwatersheds

4-1 Long Term Sediment Deposition near Searsville Lake
4-2 Total Erosion and Erosion by Grain Size Contributed to Streams in Searsville Lake Watershed from 1995 to 2000
4-3 Total Human-Related Erosion and Erosion by Grain Size Contributed to Streams in Searsville Lake Watershed from 1995 to 2000
4-4 Reconciliation of the Searsville Lake Sediment Budget, 1995 to 2000
4-5 Natural and Human-Related Erosion Per Unit Area by Sub-subwatershed in the Searsville Lake Watershed
4-6 Simplified Searsville Lake Sediment Budget Over Three Different Time Periods

5-1 Total Erosion and Erosion by Grain Size Contributed to Streams in Los Trancos Watershed from 1995 to 2000
5-2 Human-Related Erosion and Erosion by Grain Size Contributed to Streams in Los Trancos Watershed from 1995 to 2000
5-3 Reconciliation of the Los Trancos Sediment Budget, 1995 to 2000
5-4 Natural and Human-Related Erosion Per Unit Area by Sub-subwatershed in the Los Trancos Watershed
5-5 Simplified Los Trancos Sediment Budget Over Two Time Periods

6-1 Total Erosion and Erosion by Grain Size Contributed to Streams in Bear Watershed from 1995 to 2000
6-2 Human-Related Erosion and Erosion by Grain Size Contributed to Streams in Bear Watershed from 1995 to 2000
6-3 Reconciliation of the Bear Sediment Budget, 1995 to 2000
6-4 Natural and Human-Related Erosion Per Unit Area by Sub-subwatershed in the Bear Watershed
6-5 Simplified Bear Sediment Budget Over Two Time Periods

7-1 Suspended Sediment Transport Measurements in San Francisquito Creek
7-2 Annual Erosion and Annual Erosion by Grain Size Contributed to San Francisquito Creek from 1964 to 1998
7-3 Summary of Reported Excavation at Highway 101
7-4 San Francisquito Creek Reach Characteristics
7-5 Summary of Eroding Bank Length from RHAA (2000)
7-6 Average Annual Sediment Budgets at the San Francisquito gage at Stanford with and without Searsville Dam

8-1 Summary of Long-term Dominant Erosion Processes

List of Figures

1. San Francisquito Watershed Boundaries
2. San Francisquito Watershed Slope Map
3. San Francisquito Creek Geology
4. Conceptual Model of Erosion in San Francisquito Watershed
5. Sediment Transport Modes (in text)
6. Natural Erosion (yd^3/acre per year) in San Francisquito Sub-subwatersheds from 1995 to 2000
7. Human-Related Erosion (yd^3/acre per year) in San Francisquito Sub-subwatersheds from 1995 to 2000
8. Human-Related Erosion as a Percentage of Total Erosion in San Francisquito Sub-subwatersheds.

List of Appendices

A. Summary of Stream Channel Observations: Searsville Lake, Los Trancos, Bear and San Francisquito Subwatersheds
B. Searsville Lake Detailed Sediment Budget (1995-2000)
C. Bear and Los Trancos Detailed Sediment Budget (1995-2000)
D. Sources of Information for the San Francisquito Subwatershed Sediment Budget

1. INTRODUCTION

The objective of Task 5 is to develop a rapid sediment budget for San Francisquito Watershed, one which quantitatively describes the volumes of sediment mobilized on hillslopes, the volumes contributed from hillslopes to streams, the transport and storage of this sediment through the stream network, and the yield or volume leaving the watershed. Complete budgets can be very detailed; however, the sediment budget constructed for San Francisquito Creek is intended to address specific questions regarding long-term changes in sediment transport (water quality) and stream characteristics, which simplify the analysis. It is intended to address the following questions (see Reid and Dunne 1996):

- Sediment Sources: What are the major or most important types of natural and man-made sources of erosion and where do they occur? What are the approximate amounts of sediment from each source type over time and what portions of the totals have been contributed to streams?
- Sediment Sizes: What are the approximate grain size distributions of sediment from each source, particularly of the portions contributed to streams?
- Sediment Storage: What are the volumes and grain sizes of sediment in storage along the streams? What are the volumes of sediment that are excavated or removed from streams? Where are sediments deposited?
- Sediment Transport or Yield: What are the rates of sediment transport through streams and out of the sub-watersheds?

Identifying the contribution of human activities to erosion, transport and deposition is a key objective of the budget.

The sediment budget is based on existing studies of erosion, transport and deposition in San Francisquito Creek Watershed, as summarized in the Historic Conditions Analysis (Task 4.1), supplemented by air photo measurements and field observations. This earlier report demonstrated that sediment transport and deposition had been measured in most of the major subwatersheds, although for different periods of time in each. Few studies have measured erosion of sediment from sources such as landslides, bank erosion, disturbed soils, or roads. This information was lacking in most, but not all, subwatersheds.

In order to best accommodate the different periods of time and the different information on erosion, transport and deposition of sediment we developed separate sediment budgets for the following groups of subwatersheds (Figure 1):

- Searsville Lake Watershed, including the Corte Madera, Alambique, Martin, Sausal and Westridge subwatersheds
- Los Trancos Creek
- Bear Creek, including the Bear Creek, Bear Gulch and West Union Creek subwatersheds

- San Francisquito Creek subwatershed, from Searsville Dam to San Francisco Bay

Each of these groupings of subwatersheds has either short-term or long-term sediment transport or deposition measurements at their outlets that allow closure of the sediment budget by constraining erosion volumes or that permit estimation of important erosion components by balancing erosion, deposition and transport. However, the approach to the budget for each group of subwatersheds differs because of the different information on erosion and sediment transport and the nature of the significant erosion processes.

The sediment budgets separate coarse – sand, gravel, cobbles and boulders – and fine – silt and clay – sediments. Coarse sediments are of most concern for stream processes and long-term aquatic habitat. Fine sediments impact water quality. One goal is to extend the sediment budgets over as long a time period as possible. Generally, detailed measurements of erosion, transport and deposition are only available for the past few years. Consequently, the budgets are often very detailed for recent years and then become less detailed and more approximate as they are extended back in time by various assumptions.

2. THE SAN FRANCISQUITO WATERSHED

2.1. Physiography and Geology

The San Francisquito Creek watershed has an area of about 45 mi^2, most of which lies in the Santa Cruz Mountains southwest of Palo Alto. The overall watershed has been divided into 10 subwatersheds: San Francisquito, Corte Madera, Los Trancos, Alambique, Martin, Sausal, Westridge, Bear, Bear Gulch, and West Union creeks. Figure 1 shows the boundaries of the subwatersheds as well as their sub-subwatersheds. The Task 4.1 Historic Conditions Analysis Report provides details on their physiography.

The San Andreas Fault Zone (SAFZ) is the most prominent feature in the San Francisquito Creek watershed, bisecting the watershed along a northwest-southeast direction. The steep, upper watershed lies southwest of the SAFZ in the northern Santa Cruz Mountains, whereas more gradually sloping areas lie to the northeast (Figure 2). Unstable slopes and active landsliding are predominantly found southwest of the SAFZ (Wentworth *et al* 1997). This area corresponds to the Santa Cruz Mountain Upland erosional and depositional province of Brown and Jackson (1973).

The upper San Francisquito watershed lies east of the crest of the northern Santa Cruz Mountains and southwest of the SAFZ. The geologic formations in this part of the northern Santa Cruz Mountains consist of Tertiary sedimentary rocks, primarily sandstone, mudstone and shale (Figure 3). The northern Santa Cruz Mountains have had an average uplift rate of about 0.1 to 0.4 mm/year during the Quaternary, significantly less than the southern Santa Cruz Mountains (see Burgmann *et al* 1994; Anderson 1994). Stream incision into bedrock has been an important component of the development of these mountains and the broad alluvial fans and alluvial plain deposited along the shore of San Francisco Bay provide a record of the erosion that has occurred (Anderson 1994).

Tertiary sedimentary rocks and the Franciscan Complex underlie the foothills northeast of the SAFZ. Large areas of greenstone and graywacke, part of the Franciscan complex, underlie the southern part of the Los Trancos watershed (Figure 3). This area corresponds to the Bay Hills and Foothills erosional and depositional provinces of Brown and Jackson (1973).

The boundary or contact between the bedrock in the upper watershed and the unconsolidated materials around San Francisco Bay lies close to Alameda de Las Pulgas Road, along the Pulgas Fault (Fio and Leighton 1994; Metzger 2002). The unconsolidated material is an alluvial apron, consisting of coalesced deposits from the tributaries draining to San Francisco Bay during the Pleistocene and Holocene. It is thick near San Francisquito Creek (more than 1,000 feet) and includes lenses or layers of Bay Muds deposited during marine transgressions. San Francisquito Creek is well incised into the alluvial apron deposits (Helley *et al* 1979).

Pleistocene alluvial deposits also fill the broad valleys along the SAFZ in the upper watershed, such as Portola Valley and Woodside; Los Trancos Creek flows through coarse-grained Pleistocene alluvial fan and stream terrace deposits along much of its course, as does upper San Francisquito Creek (Helley *et al* 1979). Upper Corte Madera Creek flows through the poorly consolidated Santa Clara formation, consisting of lacustrine and alluvial gravels and sands.

Metzger (2002) prepared a geological profile along San Francisquito Creek downstream of Alameda de Las Pulgas Road based on well records. It shows a layer of coarse channel bed material (gravel, cobbles and boulders) extending downstream from Alameda de Las Pulgas Road as far downstream as Middlefield Road. This coarse material overlies a sandy deposit that continues under the streambed to the Palo Alto Municipal Golf Course. A thick layer of bay sediments with lenses of alluvium extends at depth beneath the sand upstream to about San Mateo Drive. These bay sediments are underlain at depth by older, more consolidated alluvium.

2.2. Conceptual Models of Erosion, Transport and Deposition

Over the long-term, landscape development in the San Francisquito Watershed, particularly in the Santa Cruz Mountains, results from channel incision into uplifted bedrock (Anderson 1994; Burgmann *et al* 1994). Incision in response to uplift rates maintains steep, often convex, valley sides, resulting in shallow landslides on the lower, steep sections of soil-mantled slopes and bedrock landslides on slopes near the overall threshold angle for failure (Burbank 2002). As documented in Brown and Jackson (1973), Kittleson et al (1996) and in the Historic Conditions Analysis, debris slides and flows and deep-seated landslides appear to be the dominant erosion process in the Santa Cruz Mountains. Abundant landslides occur every five to ten years, usually during severe storms or infrequent large earthquakes. Channel incision and bank erosion during severe storms undermine the toes of slopes and remove talus, playing an important role in initiating shallow landslides near the stream. Surface erosion is prominent on disturbed slopes and along roads and trails.

Landslides are less common in the Bay Hills and Foothills to the northeast of the San Andreas Fault Zone. Here, erosion is primarily from downslope movement of deep soils and bedrock by creep and deep-seated landslides (Brown and Jackson 1973). Sheet or surface erosion and gullying are also common, particularly where vegetation has been removed and soils disturbed.

The above describes the general nature of erosion in the San Francisquito Watershed. However, the frequency and areal extent of erosion processes is affected by both natural and human factors. Figure 4 provides a flow diagram that links the various elements that affect sediment production and transport. Human activities, particularly through land use and urban development, affect erosion and sediment transport in several ways. Vegetation removal and soil disturbance directly affect rates of shallow landsliding and surface erosion. Road construction, use and maintenance are particularly significant activities, as they may cause shallow or deep-seated landslides through failure of the road prism, contribute to downslope instability by re-distributing surface and groundwater flows, and result in surface erosion along the road surface, cutslopes or ditches.

Changes to stream hydrographs that result from creation of impervious area in urban developments are also potentially important human impacts on erosion and sediment transport. GeoSyntec (2002) provides an overview and conceptual model of urban alteration of hydrographs ("hydromodification") around San Francisco Bay for the Santa Clara Valley Urban Runoff Pollution Prevention Program. Typically more frequent small to moderate peak flows increase sediment transport and stresses on banks, often leading to channel incision, bank erosion, and widening.

Land use such as clearing or vegetation conversion, fire, forest harvesting, road construction, soil compaction from grazing and loss of wetlands may also affect peak flows. Intensive forest harvesting, agriculture and grazing are thought to have been significant in the San Francisquito Creek watershed in the past and may still be locally important. While there are no specific studies in San Francisquito Creek watershed, urban development now appears to be the most important land use that potentially alters stream hydrographs in the San Francisquito Watershed (see Section 3).

In addition to stream erosion that results from altered hydrology, there may also be erosion that results from direct impacts on streams. These include removal of riparian trees, bank protection or instream structures, bridges and culverts, gravel removal or other activities in the stream environment zone. Long encroachments in the channel or floodplain by roads, levees or other features can also concentrate flows in the main channel, resulting in channel incision and bank erosion.

The steep tributaries in the Santa Cruz Mountains are deeply incised and often confined. Little of the sediment that enters streams from erosion on hillslopes is deposited along the stream or on floodplains. This occurs because of the relatively fine sediments contributed from the hillslopes, efficient transport, and limited depositional areas. Nolan (1988; also Nolan and Marron 1985) describes a typical pattern of scour in steep, upper reaches with minor aggradation in lower reaches that is removed by storms over the next few months. Sediment storage in steep tributaries occurs behind logjams and in a few protected locations or sites.

Deposition in the upper watershed primarily occurs along stream courses in the San Andreas Fault Zone, on the fans constructed by Corte Madera, Sausal and Alambique Creeks at the head of Searsville Lake, and in Searsville Lake. Sediments range in size from cobbles to sand, with most of the material being sand. Further downstream, sand is deposited along lower San Francisquito Creek (downstream of Pope Chaucer Bridge) and on its delta in San Francisco Bay. The finest sediment fractions are carried past the delta, into San Francisco Bay.

2.3. Defining Sediment Transport

The total sediment load can be divided based on the mode of transport, into suspended and bed load (Figure 5). Suspended load consists of the finer sediment maintained in suspension by turbulent currents.

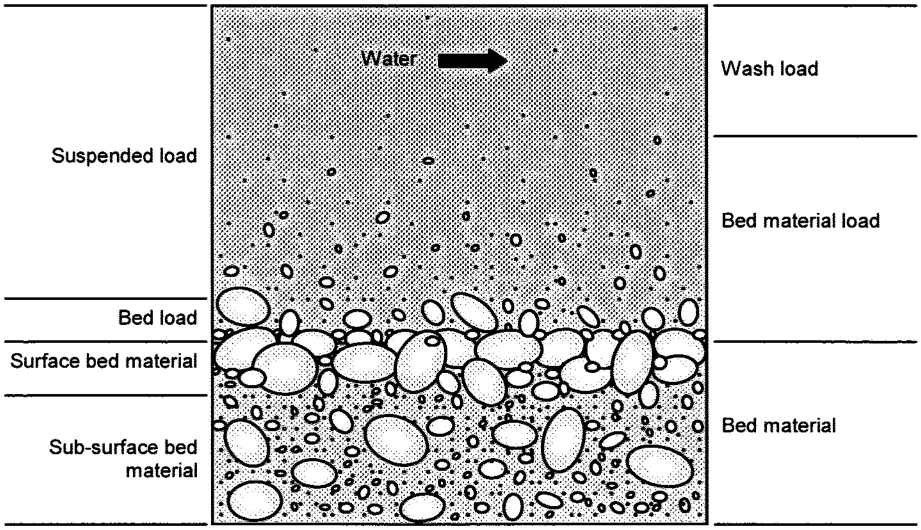


Figure 5. *Sediment transport modes*

Bed load consists of the coarser particles transported along the bed by rolling, sliding, or saltating. The boundary between the size of particles moved in suspension or as bed load is not precise and may vary with the flow strength; the greater the flow, the coarser the sediment that can be suspended by turbulence.

The total sediment load can also be divided by its presence in the streambed, into bed material and wash load (Figure 5). Particles that are found in significant quantities in the bed and are exchanged with the bed material during transport are part of the bed material load. Wash load consists of fine sediments (usually silt and clay) that are continuously maintained in suspension by the flow turbulence and, thus, are not found in the bed in significant quantities. Under this division, total sediment load is bed material load plus wash load.

Bed material transport depends on hydraulic variables, which are closely related to water discharge, and consequently can often be calculated from knowledge of the bed material and the hydraulic characteristics of a particular site. The wash load is determined by its supply from upstream sources and it may be partly independent of water discharge. Typically, wash load is measured as part of a sediment-gaging program.

3. HYDROLOGY

3.1. Stream Gauging Records

The "San Francisquito Creek at Stanford University (11164500)" gage, located on the Stanford Golf Course upstream of Junipero Serra Boulevard, provides the best long-term record of flow in San Francisquito Creek with measurements from 1931 to 1941 and then from 1951 to present. This gage has a watershed area of 37.5 mi^2 and measures the flow from the Santa Cruz Mountains and Bay Foothills.

The stream gages operated on San Francisquito Creek and its tributaries by the USGS are summarized in Table 3-1.

Table 3-1: USGS Stream Gages on San Francisquito Creek and Tributaries

Gage Name	*Gage Number*	*Period of Record*	*Area (mi^2)*	*River Mile* [1]
At Searsville Dam (staff gage on spillway crest)	None	1892-1913	–	12.7
At Stanford University	11164500	1931-41; 1950 to present	37.5	7.6
At Menlo Park	11165000	1931-1941	38.3	5.4
At Palo Alto	11165500	1934-36	38.4	4.6
Los Trancos Ck near Stanford University	11163000	1930-41	–	–
Los Trancos Tributary near Stanford University	11163200	1958-66	0.42	–
Los Trancos Ck at Stanford University	11163500	1930-41	7.46	–

1. River mileage along San Francisquito Creek from Corps of Engineers (1972)

Balance Hydrologics, Inc also operates stations on the tributaries to San Francisquito Creek for Stanford University. Measurements began in 1997 on Corte Madera Creek at Westridge Road and in 1995 on Los Trancos Creek at Arastradero Road and they continue to the present (Owens, Chartrand, and Hecht 2002).

Crippen and Waananen (1969) reported flow and sediment measurements on three small tributaries in the Bay Foothills, from 1959 to 1965, showing the effect of suburban development on their hydrologic regime. Their study included the Los Trancos Creek Tributary described in Table 3-1.

3.2. Climate and Hydrology

San Francisquito Creek has a Mediterranean climate, with warm, dry summers and mild, wet winters. Average annual precipitation varies from 15 inches at Palo Alto (Metzger 2002) to about 40 inches in the upper watershed (Rantz 1971). The Corps of Engineers (1972) estimated an average annual precipitation over the watershed of about 32 inches.

Average annual flow at the Stanford University gage is 21.4 cfs, equivalent to 7.7 inches of runoff, or about 25% of average annual precipitation.

nhc *et al* (2002) extended the record of annual flows from 1899 to the 2000 water years at the Stanford gage, filling missing years in the recorded flow record through correlation with nearby long-term gages. Examination of this record shows distinct periods of high and low annual flows, with the periods of high flows spaced roughly 15 to 20 years apart. Streamflow has been particularly high from 1995 to 2000; other periods of consistent high flows include 1899 to 1911 and from 1937 to 1945.

The flood of record on San Francisquito Creek at the Stanford University gage occurred in 1998 with a peak of 7,200 cfs. Other notable floods – those exceeding 5,000 cfs based on reconstructed records – have occurred in 1894, 1895, 1911, 1955 and 1982 (Kittleson *et al* 1996; see also Corps of Engineers 1972). The Corps of Engineers (1972) also notes that between 1910 and 1972 San Francisquito Creek overflowed its banks eight times – in 1911, 1916, 1919, 1940, 1943, 1950, 1955 and 1958. It also overflowed its banks in 1982 and then again in 1998 (Cushing 2000). Levees and channel modifications now contain the flows that overtopped the banks earlier in the twentieth century. As described by the Corps of Engineers (1972) and Cushing (2000) overflow now mostly occurs along the lower part of the creek, downstream of Middlefield Road, during extreme floods.

The tributaries to San Francisquito Creek in the upper watershed are mostly deeply incised. Flood insurance studies have been completed for Portola Valley and Woodside (US Department of Housing and Urban Development 1978; 1979). These studies show that peak flows are contained within the banks of most creeks, with the exception of Corte Madera and Sausal Creeks. Aggradation on the fan of Corte Madera Creek at the head of Searsville Lake now results in flooding along Family Farm Road and adjacent properties (**nhc** and JSA 2000).

Low flows at the Stanford University gage typically occur in the late summer or early fall, before winter rains begin. Downstream of this gage, the channel bed over the fan deposits is effluent and low flows infiltrate to groundwater, leaving much of the streambed dry for about six months of the year (Metzger 2002). Upstream of the gage, where San Francisquito Creek flows over bedrock, streamflow losses are negligible.

Most of the streamflow losses or infiltration to groundwater occurs between San Mateo Drive and Middlefield Road where San Francisquito Creek crosses the Pulgas fault. Further downstream, losses are minimal and groundwater returns may supplement stream flows. Storm drains also supplement natural flow at various sites along the reach and water chemistry measurements indicate that during moderate and low flows that streamflow downstream of San Mateo Drive is a mix of natural flows from the upper watershed and urban runoff (Metzger 2002).

3.3. Development and Hydrology

As discussed earlier, modifications to flood hydrology from urban development may potentially result in stream instability, channel incision or increased bank erosion.

Unfortunately, there are no detailed hydrologic modeling studies of San Francisquito Creek that compare existing peak flows or hydrographs to those that might have occurred prior to development. Consequently, potential modification of hydrology must be assessed indirectly from measurements of impervious area prepared from land use data. EOA Inc (1998) estimated total impervious cover in the San Francisquito watershed from the 1995 Association of Bay Area Governments (ABAG) land use combined with estimates of impervious cover for 40 land use categories. They estimated total impervious cover as 22% of the watershed area. The Santa Clara Basin Watershed Management Initiative (2003) subsequently estimated impervious cover of 20.8% as of 1995 and projected an impervious cover of 26.1% for the development expected as of 2020. These estimates refer only to the entire watershed; a breakdown by subwatersheds is not provided by either of these references.

There are no studies of the relationship between impervious cover and channel stability that are specific to the San Francisco Peninsula or San Francisco Bay. However, studies from Washington (Booth and Jackson 1997) suggest that channel instability is observed for watersheds with greater than 10% impervious cover. (Booth and Jackson refer to effective impervious cover, which is less and may be much less than total impervious cover.) Based on the above, it seems likely that urban development in Palo Alto, Menlo Park and East Palo Alto have increased the frequency of channel forming flows and also the duration of peak flows in San Francisquito Creek, thus increasing sediment transport and bank erosion. Levees to maintain flood flows in the channel and human modifications of stream banks likely also increase instability and erosion. Detailed hydrologic and geomorphic modeling would be needed to assess the magnitude and significance of urban development on erosion along San Francisquito Creek.

The lower watershed is substantially urbanized; however, the upper watershed is lightly developed, with low and moderate density residential areas in Portola Valley and Woodside, some agriculture along the SAFZ, and open space areas and parks on the steep slopes of the Santa Cruz Mountains. The Coordinated Resource Management and Planning (CRMP) Task Force (1998) provided estimates of impervious cover for the upper subwatersheds, based on 1983 land use (Table 3-2). While not explained in the text, it appears that the quoted values refer to total rather than effective impervious area. The impervious area estimates from CRMP may be reasonably consistent with existing conditions, as only limited development has occurred in the upper watershed in the past twenty years.

Based on the impervious cover quoted in Table 3-2, and recognizing that total impervious cover overestimates effective impervious cover, it seems likely that urban development and creation of impervious areas in Searsville Lake, Los Trancos and Bear subwatersheds only contribute in a minor way to altered flows and channel instability in the main streams in these subwatersheds. However, flows may have been altered in some sub-subwatersheds. The watershed of Westridge Creek (part of SL-02) is mostly covered by residential development with lots of more than one acre. Typical total impervious areas for such developments are about 20% and some modification of peak flows might be expected as a result. Martin Creek (MC-01) and Bull Run Creek (SC-02) also exhibit more roads and houses than other sub-subwatersheds in the Santa Cruz Mountains and their peak flows may also have been affected by development.

Table 3-2: Total Impervious Cover and Road Densities for San Francisquito Subwatersheds

Subwatershed	***Area (mi^2)***	***Percent Impervious Cover*** [1]	***Road Density*** [2] ***(mi/mi^2)***	
			Paved	*Unpaved*
Searsville Lake (Corte Madera, Alambique, Sausal, Dennis Martin and Westridge)	14.6	6%	4.8	2.9
Los Trancos	7.6	4%	4.7	1.9
Bear (Bear, Bear Gulch, and West Union)	11.6	7%	4.3	1.7
San Francisquito Creek from Searsville Dam to Junipero Serra Boulevard (SF-10 and SF-11)	3.4	12%	6.3	2.5
Total Watershed [3]	47.1	21%	–	–

1. From CRMP (1998); refers to 1983 land use. Assumed to be total impervious area.
2. Paved and unpaved road lengths from most recent revision of USGS maps (see **nhc** and JSA 2003a; Appendix E).
3. Average of EOA (1998) and SCVWMI (2003) percent impervious cover.

Crippen and Waananen (1969) examined the effect of suburban development on the hydrologic regime of three small tributaries in the San Francisquito Creek watershed between the dam and Junipero Serra Boulevard. They identified large increases in storm and annual runoff, a more rapid response to precipitation, an increase in the occurrence of frequent floods, and a change from ephemeral to perennial flow as a result of golf course irrigation resulting from conversion of rural lands. Hydrograph changes apparently resulted in channel incision and other adjustments along these tributaries.

Roads and trails in the Santa Cruz Mountains, where there is little impervious area from development, may play a role in modifying hydrology. These are mostly the unpaved roads listed in Table 3-2. Studies of forest road impacts on hydrologic processes have found that roads can increase peak flows by intercepting subsurface flow and dispersed overland flow from hillslopes and conveying it more rapidly via road surfaces and ditches to the stream channel network. In this way, roads serve to drain runoff from the landscape more quickly by increasing the effective length of channels in a watershed (i.e. increasing drainage density). The following attributes of road systems affect the degree to which they alter hillslope drainage:

- Location on hillslope: the greatest alteration results from mid-slope roads.
- Orientation on hillslope: the greatest alteration is by roads cutting across slopes.

- Cut bank height: the greatest alteration occurs when the cut bank intersects the complete subsurface flow zone.
- Road surface and ditch roughness: the greatest alteration occurs when roads and ditches are unvegetated.
- Connectivity to stream channels: the greatest alteration is from roads with long continuous grades and few cross-drains that lead to stream channel crossings.

The generation of overland flow on the compacted road surface itself can also be a factor. However, in most studies, this was considered secondary to the other effects because the impervious area of the road surfaces is only a small percent of watershed area.

Inspection of maps and air photographs show that the main roads through the Santa Cruz Mountains are on the valley bottoms (in the SAFZ) or on the crest of the Santa Cruz Mountains (Skyline Boulevard); few roads are found on upper slopes and few of these are mid-slope roads that might intercept subsurface flows. Main roads that cross the Santa Cruz Mountains, such as Kings Mountain Road, Bear Gulch Road and Highway 84, and the trails in the Mid-Peninsula Regional Open Space typically climb ridges and do not typically cross slopes. Many of the trails do not have ditches connecting their surfaces to the stream network. It is our opinion that the existing roads and trails in the upper watershed may increase frequent flood peaks by a few to 10% or so in some sub-subwatersheds, depending on their degree of hydrologic connectivity, and have little or no effect on infrequent, large peaks. Such results are consistent with hydrologic modeling of forest roads in Washington with similar road densities (**nhc** 2003). Detailed hydrologic and geomorphic modeling would be needed to assess the magnitude of changes in flood hydrology from roads and their contribution to channel instability and erosion.

Overall, the land use in the San Francisquito Creek watershed suggests significant modification to the frequency and duration of peak flows in San Francisquito Creek and little or no modification of hydrographs in the tributaries in the upper watershed. Low-density residential development and roads may modify peak flows in some sub-subwatersheds, particularly Westridge Creek and possibly Dennis Martin and Bull Run Creeks.

4. SEARSVILLE LAKE SEDIMENT BUDGET

4.1. Approach

The Searsville Lake Watershed, in the Santa Cruz Mountains southwest of Palo Alto, flows to Searsville Lake and has an area of about 14.6 mi^2. This watershed includes the Corte Madera, Sausal, Martin, Alambique and Westridge subwatersheds.

Deposition in Searsville Lake provides a partial record of 108 years of sediment transport from the Searsville Watershed. Detailed measurements of sediment transport for the period from 1995 to 2000, which includes the very large flood in 1998, are used to constrain estimates of erosion over that same period. This detailed budget identifies the relative importance of different sources, human modifications to erosion, and those areas that contribute the most sediment during a period of unusually high sediment discharge.

The long-term deposition record in Searsville Lake is then used to constrain estimates of contributions from different sources for both dry and average or typical conditions, based on adjustment of the detailed budget.

4.2 Sediment Transport to Searsville Lake

Deposition in Searsville Lake provides a long record of sediment transport or yield from Corte Madera, Sausal, Westridge and Alambique Creeks. Repeated reservoir surveys measured average sediment deposition from 1892 to 1913; 1913 to 1929; 1929 to 1946; 1946 to 1995; and from 1995 to 2000 (**nhc** *et al* 2002). Deposited volumes are summarized in Table 4-1 below.

Table 4-1. Long-Term Sediment Deposition near Searsville Lake

Period	*Annual Deposition (acre-feet/yr)*	*Annual Sediment Yield (yd^3)* [1]		
		Total [2]	*Corte Madera* [2]	*Remainder* [2]
Searsville Lake Deposition				
1892-1913	17.4	31,000	25,000	6,000
1913-1929	3.6	6,500	5,200	1,200
1929-1946	7.2	13,000	10,000	2,500
1946-1995	7.1	13,000	10,000	2,400
1995-2000	23.5	42,000	34,000	8,000
1892-2000	9.4	17,000	14,000	3,000
Searsville Lake and Fan Deposition				
1995-2000	39	70,000	57,000	13,000

1. Sediment yields adjusted to account for 10% loss over dam crest.
2. Assumes that Corte Madera contributes 81% of the total sediment to Searsville Lake (**nhc** et al 2002).

Deposition in the reservoir underestimates total sediment transport from the Searsville Watershed. This occurs for two reasons. First, the finest grain sizes are carried over Searsville Dam to San Francisquito Creek so they are not included in the total, and second, coarse sediment that has accumulated on the fans of Corte Madera, Sausal and Alambique Creeks upstream of the reservoir has not been surveyed, except between 1995 and 2000 (**nhc** *et al* 2002). The sediment that passes over the dam amounts to about 10% of the incoming load; the yields quoted in Table 4-1 have been increased to account for this loss (**nhc** *et al* 2002). However, it is not simple to adjust for historic deposition on fans at the head of the lake because the portion of the total load deposited there has likely increased over time. As such, adjustments are only available for the most recent period. Table 4-1 suggests that deposition on the fan may add half as much again to the sediment yields quoted above, mostly consisting of sand, gravel and cobbles.

Owens, Chartrand and Hecht (2002) summarize the results of their flow and sediment gaging on Corte Madera Creek at Westridge Road, upstream of Searsville Lake, for the water years from 1997 to 2001. Their measurements show that most of the sediment deposited in Searsville Lake and on the fan was moved during the 1998 water year. The total measured load consists of about 25% bed load and 75% suspended load. The bed load is assumed to consist entirely of sand and coarser sediment. No particle size distributions are available for the suspended load, so we have assumed that it is one-third sand and two-thirds silt and clay. On this basis, the total load is divided into about 50% coarse load (sand, gravel and cobbles) and about 50% fine load (silt and clay). The fine sands included in the coarse load are not be found in the bed material in large quantities and so are not properly part of the bed material load.

4.3. Sediment Sources

OVERVIEW

Sediment sources in the Searsville Lake watershed that contribute to streams can be divided into two broad categories; discrete sources, such as landslides and gully erosion, and chronic sources, such as bank erosion, sheetwash or surface erosion, and other hillslope erosion processes. As described earlier, landslides are thought to be the dominant erosion process and the greatest effort has applied to documenting this source, with less effort applied to those sources that are thought to be less important overall. The nature of each source, how we identified them in the watershed, and the estimated rates of erosion for the 1995 to 2000 period are described below and summarized in Appendix B. Table 4-2 summarizes erosion volumes from 1995 to 2000 contributed to streams and indicates the range of uncertainty in these estimates and the likely grain sizes of the erosion products.

LANDSLIDES

The inventory of landslides in the Searsville watershed was prepared from two different sources. Frey (2001) mapped landslides along stream channels and classified them as either small or large; the surface area of small landslides was measured whereas large landslides were simply noted (Appendix B). Her surveys followed the large flood of 1998 and her measurements are thought to be fairly representative of the total number of landslides that occurred along valley bottoms near streams from 1995 to 2000, although a few that occurred after her survey may not be included. We estimated the volumes eroded from her small landslides by multiplying the surface area by an average depth of 4 feet, typical for the soil slips or small landslides measured in the Santa Cruz Mountains by Ellen and Weiczorek (1988). Field inspection confirmed that average depths were about 4 feet, but they varied considerably from one slide to another. The eroded material is typically sand with small quantities of gravel and up to 25% silt and clay (see Wentworth et al 1985; Ellen and Weiczorek 1988). We assumed that all the sediment from these landslides entered streams.

Table 4-2: Total Erosion and Erosion by Grain Size Contributed to Streams in Searsville Lake Watershed from 1995 to 2000

Sediment Source	*Total Erosion (yd^3)*	*Likely Range (%)*	*Comment*	*Coarse Sediment (yd^3) [1]*	*Fine Sediment (yd^3) [1]*
Small streamside	179,000	±25%	Depth uncertain	134,000	45,000
Large streamside	18,000	±75%	Rough estimate	13,000	5,000
Hillslope landslides	80,000	±50%	Depth uncertain	60,000	20,000
Bank Erosion	20,000	±50%	Unit volume uncertain	15,000	5,000
Channel Incision	8,000	±50%	Depth uncertain	8,000	0
Road Erosion	3,000	±75%	Likely overestimated	1,000	2,000
Scar/Scarp Erosion	3,000	±75%	Rough estimate	1,000	2,000
Sheet Erosion	700	±75%	Rough estimate	0	700
Gully Erosion	4,000	±75%	Length and volume uncertain	2,000	2,000
Totals	***317,000***	***196,000 to 441,000***		***234,000***	***82,000***

1. Coarse sediment is sand and larger (>0.063 mm); fine sediment is silt and clay (<0.063 mm).

Frey identified considerably fewer large landslides than small ones. We do not have a good indication of the size of these landslides so we assumed that they averaged about twice as large as the small landsides, or about 0.08 acres. We assumed the same depth, so the large landslides produced an average sediment volume of 600 yd^3, about double that of the average small landslide. There is considerable uncertainty in the estimated volumes for each landslide and for the total volume from this source. We assumed that all the sediment from these landslides entered streams.

Large landslides on slopes away from stream channels were measured from 2000 stereo air photos (see **nhc** and JSA 2003a; see Appendix D). The inventory focused on landslides with disturbed areas that exceeded 500 yd^2 (0.10 acres) as this appeared to be about the minimum size that would be clearly visible through the forest cover, given the air photo scale. This minimum size is much larger than the average size of the small landslides identified by Frey (2001). We deleted any landslides from the air photo inventory that appeared to match or correspond to sites where Frey had identified landslides, however, for the most part, the landslides she identified could not be identified on the 2000 air photos. We assumed that the landslides that were bare of vegetation on the 2000 air photos occurred during the 1998 storm or at least after 1995 and were part of the yield from 1995 to 2000. We have assumed that these landslides primarily contributed sand and coarser material, with up to 25% silt and clay.

The surface area of each landslide was measured and an eroded volume calculated based on an estimated average landslide depth of 5 ft, typical for medium and large landslides observed in the Santa Cruz Mountains by Ellen and Weiczorek (1988). The portion of the landslide volume entering a stream was estimated from the general appearance of the landslide and its deposit, if visible. These landslides were divided into natural and man-made types, the latter including those landslides that initiated adjacent to road prisms, where they may have been initiated by slope loading or drainage diversion, or those that initiated in areas disturbed by development or other land uses.

Two large landslides were observed during field inspections that were not incorporated in the inventory. The Alpine Road landslide on upper Corte Madera Creek appears to be a deep-seated rotational failure that has a displaced volume of around 10,000 yd^3 and confined Corte Madera Creek along its toe. The slide apparently occurred before 1995 although it has been active since then. Frey measured bank erosion and small landslides along the toe of the failure and their volumes are incorporated in the budget although the overall volume is not.

A large debris flow fan has been deposited in Corte Madera Creek at the mouth of Damiani Creek. Frey (2001) notes that much of this deposit formed during the storms of 1998. However, field inspection of vegetation on and near the deposit indicates that it may have been in place for much longer. It appears that much of the coarse sediment carried down Damiani Creek remains in the fan; fine sediment was likely carried downstream. We did not include the debris flow volume in the 1995-2000 sediment budget but bank erosion through the landslide deposit is included under stream erosion.

STREAM EROSION

Stream erosion is subdivided into bank and bed erosion. Frey (2001) reported bank erosion for all major streams, identifying the percentage of stream reaches that exhibited either moderate or severe bank erosion. We have assumed that all of the observed erosion occurred after 1995 and most occurred during the 1998 flood. Based on field inspections of Corte Madera Creek and its tributaries, we estimated that banks were about 3 feet high; severe erosion was assumed to consist of 2 feet of retreat on each bank; moderate erosion to consist of 0.67 feet of erosion on each bank. These values likely overestimate the erosion that actually occurred. We have assumed that all the material eroded from banks entered the stream and that the sediment was dominantly sand and gravel, typical of the observed alluvial deposits.

Frey (2001) also noted areas of channel incision in her description of each stream. For the tributaries to Corte Madera Creek and other streams in the Searsville Watershed, we assumed that incision averaged about 1 foot, or 0.3 yd^3/yd, assuming that channel bottoms average about eight feet wide (Appendix A). It was assumed that all material entered the stream and that it was nearly entirely coarse sediment – gravels and cobbles. The record of incision on the tributaries may not be complete, and it is likely that only the more significant incised sections were identified. Incision along Corte Madera Creek was estimated from field inspections in the summer of 2003. These are discussed in detail in the following section and summarized in Appendix A.

STREAM DEPOSITION

Frey (2001) also mapped areas of deposition or aggradation along streams. In steep tributaries, deposition primarily occurred upstream of logjams or in sheltered locations along the channel. Along Corte Madera Creek and other large streams, deposition consisted of sand and gravel in pools and on bar tops, often up to 1 foot or so thick. Based on field inspections, we have assumed that deposition averages about 0.5 feet over the lengths of stream identified as aggrading by Frey (2001), or about 0.15 yd^3/yd, assuming an eight-foot bottom width. The above estimate is likely too high for the tributaries and may be too low for some sections of Corte Madera Creek. Gravel accumulation along Corte Madera Creek is not well documented and is not included in the above estimates.

Deposition is subtracted from total erosion to provide net transport from the subwatershed or sub-subwatershed. Net transport can be negative in some lower reaches of some subwatersheds, indicating net storage of sediment within the sub-subwatershed (see Appendix B).

ROAD EROSION

Erosion along roads is from chronic sheetwash on natural or gravel road surfaces, on cut and fill slopes, and from ditch erosion. Sediment is eroded from paved roads, natural or gravel surfaced roads and trails; often, trails are old roads. The length of existing roads in the individual sub-subwatersheds, both paved and unpaved, is from Appendix E of the Historic Conditions Report (**nhc** and JSA 2003a). Trails in the Searsville Watershed are included in this inventory as unpaved roads.

Erosion rates for unpaved roads are higher than for paved roads; however, the erosion rates for unpaved roads vary widely depending on climate and the frequency and type of traffic (see Reid and Dunne 1996). Road surfacing, maintenance practices, spacing of drainage structures, road slope and other factors also affect erosion from individual roads (McCashion and Rice 1983, Reid and Dunne 1984, Rice 1999). Reid and Dunne (1984) provide annual erosion rates for gravel-surfaced logging roads in mountainous watersheds, for different types and frequency of traffic, based on sediment transport measurements. Very high erosion rates occur on road segments with frequent traffic by logging trucks; much lower rates were observed for abandoned roads and those with only light vehicle traffic (McCashion and Rice 1983; Reid and Dunne 1984).

There are no studies of erosion from roads in the San Francisquito Creek watershed. Pacific Watershed Associates (2003) examined erosion along paved and unpaved (assumed mostly natural surface) roads and trails in San Mateo County Parks in Pescadero Watershed in the Santa Cruz Mountains. Predicted future surface erosion from the unpaved roads to streams averaged about 40 yd^3/mi per year over the road network, with most of the erosion expected from part of the network where long-term lowering of ditches, cut slopes, and road surfaces is assumed to average 0.2 feet/year. Pacific Watershed Associates also estimated surface erosion from trails in the County Parks in the Pescadero Watershed. For the total length of 34.4 miles of trail, erosion averaged about 1.7 yd^3/mile per year, assuming a 6-foot wide trail prism and averaging lowering of 0.2 feet/year at those sites that appeared to have chronic erosion. The blended average erosion rate for all their unpaved roads and trails is 23 yd^3/mile per year.

The estimated average erosion from Reid and Dunne (1984) for light traffic on gravel-surfaced roads is much less than that estimated by Pacific Watershed Associates – only 3.8 tonnes/km per year (5 yd^3/mi per year, assuming 1.5 tonnes/m^3). The volume entering streams would be even less than their quoted erosion value because of deposition between roads and streams.

It is our view that the average road erosion quoted by Pacific Watershed Associates would over-estimate contributions to streams if applied in the Searsville Lake watershed. Rainfall is less in Searsville Watershed, roads and trails are often distant from streams, there are relatively few stream crossings on mid and upper slopes (see **nhc** and JSA 2003b; Figure 7), and many roads and trails have no ditches or drainage structures to convey sediment to streams. We have adopted an average value that is half of their blended erosion rate (11 yd^3/mile per year) and applied it to unpaved roads in the Searsville Watershed, including both roads and trails. The sediment eroded from roads that reaches steams is assumed to be mostly silt and clay but may include some sand.

Our estimate for surface and ditch erosion from unpaved roads and trails in the Searsville Watershed is likely conservative, particularly when applied to trails. However, a conservative value seems appropriate because some erosion processes along roads are not included in the above total. The estimate does not include erosion from small failures on cut and fill slopes, which are less than the minimum area included in the air photo inventory. Field inspections indicate that cut slope failures are unlikely to enter streams as they are intercepted by road surfaces, however, some of these sediments may be later eroded by sheetwash or removed by maintenance activities. Fill and road surface failures also seem to be uncommon. Landslide maps prepared for Portola Valley and Woodside (Rodine 1975; Cummings and Spangle & Associates 1975; Dickinson et al 1992) show few active landslide scarps originating in road prisms, other than in subdivisions along Bull Run and Sausal Creeks, suggesting roads and trails are reasonably stable. Note that these maps do not include all of unpaved roads and trails in the Searsville Lake Watershed. Erosion of road crossings is also not included in the above estimate. As noted earlier, there are relatively few crossings by unpaved roads in Searsville Watershed and past failures of these crossing may not have provided a large contribution to erosion.

Erosion along paved roads results from sheetwash on cut and fill slopes, failures on cut and fill slopes, and ditch erosion. Reid and Dunne (1984) estimated that paved road erosion averages 2 tonnes/km per year (2.8 yd^3/mi per year, assuming 1.5 tonnes/m^3) and we have adopted their value for paved roads in the Searsville Lake watershed. Sediment that reaches streams is assumed to be mostly silt and clay with some sand.

Road erosion in the individual sub-subwatersheds is estimated from the above average annual rates applied to the measured lengths of paved and unpaved roads. Some road segments are expected to produce much more sediment than some others; this may result in over- or under-estimating actual road erosion. For instance, significant erosion has been observed on Alpine Road (cut and fill slopes), Highway 84 (debris flows observed during 1982 storm on cut and fill slopes) and on Kings Mountain Road (ditch erosion) and these paved roads are expected to contribute substantially more sediment than other paved road segments. Little is known about which unpaved roads and trails are significant contributors.

SURFACE EROSION

In the Searsville Watershed, surface erosion (sheetwash) is relatively rare on undisturbed, forested slopes and is usually confined to those sites where vegetation and soils are removed or disturbed, or soils are compacted, and overland flow occurs. Such sites include landslide scars, construction sites, range and agricultural lands, fire-damaged areas, and roads and urban developments. Roads and urban developments are addressed separately in preceding sections. Erosion rates from these processes have not been measured in the Searsville Lake Watershed.

Landslide scars include areas of bare earth exposed by sliding, where vegetative re-growth is still in the early stages and slide scarps at the headwall along the margin of a landslide scar. We have based estimates of scar erosion on Lehre (1982) who conducted a 3-year study of erosion rates on Lone Tree Creek, a small, mountainous, forested watershed in Marin County. He observed surface erosion of between 2 and 5 mm/year on fresh landslides. We assumed that surface erosion would average 3 mm/year, equivalent to 16 yd^3/acre of recent landslide scar, including the small and large landslides of Frey and the landslides identified from the air photo inventory. We assumed scar erosion mobilized mostly fine sediment, with some sand, and that all sediment was carried to a stream.

Lehre observed average head scarp retreat equivalent to 0.017 yd^3/yd. In Searsville watershed, head scarp lengths were estimated from landslide areas by assuming that the ratio of landslide length to width was 5. We assumed scar erosion mobilized mostly fine sediment, with some sand, and all sediment was carried to a stream. While there are uncertainties regarding the applicability of his estimates to the Santa Cruz Mountains, the yields from these processes are relatively insignificant and it was not judged necessary to refine them further.

Erosion from construction sites can be substantial, if no sediment and water management controls are in place (see Knott 1973). However, we have assumed that all winter construction and re-construction completed between 1995 and 2000 was well managed and contributed little or no sediment to creeks in the Searsville Watershed.

Lehre (1982) also estimated the average rate of surface erosion from grasslands and denuded hillslopes in Lone Tree Creek to be 4 tonnes/km^2 per year (9 yd^3/mi^2 per year, assuming 1.5 tonnes/m^3). We have applied this average rate to all the area in each sub-subwatershed around Searsville Lake, rather than just grasslands, to account for past human disturbance of hillslopes, some contributions from construction sites, or other activities not explicitly incorporated above. We assume that all this eroded material enters streams and that it consists almost entirely of silt and clay.

GULLIES AND FIRST ORDER STREAMS

Frey (2001) mapped gully locations along stream channels in the Searsville Lake watershed. However, it is unclear if she identified all gullies or only included eroding gullies. A brief inspection of large-scale maps shows that the stream network included in the GIS database of San Francisquito Creek includes very few small gullies or zero-order channels and swales. Measurements from large-scale maps suggest that the drainage density including these channels may typically be from 4 /mi to 5/mi, whereas drainage densities calculated from the stream lengths in the GIS database are typically around 2/mi (see **nhc** and JSA 2003a). Consequently, we estimating the length of gullies and zero-order channels by calculating the length of the total channel network from sub-subwatershed areas and an estimated density of 4/mi and subtracting the stream length measured in the GIS database.

Lehre (1982) estimated a gully sidewall erosion rate of 0.013 m^3/m per year (0.016 yd^3/yd per year), combining retreat rates observed on vegetated and bare walls. We have adopted his erosion rate for gullies in the Searsville Lake watershed even though it is uncertain if his rate is applicable to Searsville Watershed. Field and air photo inspection suggests that a number of the small gullies and zero-order channels have been disturbed by drainage diversion, road construction or other human activities. We have assumed that about one-third of the gully erosion in each sub-subwatershed results from human disturbance. This is a very rough estimate and is likely to over-estimate disturbance in some watershed and underestimate it in others. The sediment derived from gully erosion was assumed to be about half sand and half silt and clay and to all enter a stream.

SOIL CREEP

Soil creep includes all processes that cause soil to move downslope under gravity, such as animal burrows, frost heave, soil expansion and contraction from wetting and drying or other processes, and plastic flow. Creep occurs at slow rates on most slopes and it is most significant in moving sediment to colluvial banks along steep streams. This sediment is then eroded during floods, and the streambank erosion at the slope toe helps maintain creep. Creep rates are usually not well known and are thought to vary widely. Lehre (1982) estimated creep rates of 11 to 27 yd^3/mi^2 (5 to 12 tonnes/km^2 per year) directly to stream banks in Lone Tree Creek; Reid and Dunne (1996) quote typical rates of 10^{-3} m^3/m of stream bank per year, or up to 17 yd^3/ mi^2 for colluvial stream banks. Much higher rates occur at deep-seated landslides or other unstable sites. Brown and Jackson

(1973) quote an estimated annual contribution to streams of 1 ton/50 feet in the Moraga Valley in the Oakland Hills.

We have not included soil creep as a sediment source in our short-term budget because its contributions are later mobilized by bank erosion and we wish to avoid counting the same sediment contribution twice. However, in the long-term, creep and other slope processes carry the sediment downslope that is moved to streams by landslides and erosion of colluvial bank deposits.

4.4 Human Contributions to Erosion

Human contributions to erosion as a result of both direct and indirect (hydromodification) alterations of natural processes are summarized in Table 4-3. Direct contributions include:

- Landslides on slopes that appear to originate at roads, developments or areas disturbed by human activity
- Surface erosion of landslide scars that result from human activity
- Surface erosion from roads, and
- Surface erosion from grasslands or disturbed soils
- Gullies erosion attributed to human disturbance

Table 4-3: Human-Related Total Erosion and Erosion by Grain Size Contributed Streams in Searsville Lake Watershed from 1995 to 2000

Sediment Source	*Total Erosion (yd^3)*	*Likely Range (%)*	*Comment*	*Coarse Sediment (yd^3)* [1]	*Fine Sediment (yd^3)* [1]
Direct Contributions					
Hillslope landslides	31,000	±50%	Depth uncertain	23,000	8,000
Road Erosion	3,000	±75%	Likely overestimated	1,000	2,000
Scar/Scarp Erosion	300	±75%	Rough estimate	100	200
Sheet Erosion	700	±75%	Rough estimate	0	700
Gully Erosion	1,600	±75%	Human impact very uncertain	800	800
Indirect Contributions (Hydromodification)					
Bank Erosion and Channel Incision	3,400	±50%	Human impact uncertain	2,400	800
Small streamside	10,700	±25%	Human impact uncertain	8,000	2,700
Totals	***50,700***	***27,000 to 76,000***		***35,300***	***15,200***

1. Coarse sediment is sand and larger (>0.063 mm); fine sediment is silt and clay (<0.063 mm).

Indirect contributions include bank erosion, channel incision, and landslides along streams that may result from increased peak flows from development or bank erosion or landslides along streams that may result from encroachment onto floodplains or streams or human modification of stream banks. We have assigned an anthropogenic component to bank and stream landslide erosion as follows (Table 4-3; see also Appendix B):

- Westridge Creek (SL-02). We have assumed that half of all bank erosion and stream landslides are human-caused as a result of hydrologic modification from low-density residential development.
- Martin Creek (MC-01). We have assumed that one-quarter of all bank erosion and stream landslides are human-caused as a result of hydrologic modification from low-density residential development.
- Bull Run Creek (SC-02). We have assumed that one-quarter of all bank erosion and stream landslides are human-caused as a result of hydrologic modification from low-density residential development.
- Sausal Creek (SC-01 & SC-03). We have assumed that half of all bank erosion and stream landslides are human-caused as a result of hydrologic modification in upstream areas and modifications to stream banks from low-density residential development.
- Corte Madera Creek (CM-01 & CM-02). We have assumed that one-quarter of all bank erosion and stream landslides are human-caused as a result of floodplain encroachment and modifications to stream banks from low-density residential development through Portola Valley.
- Corte Madera Creek (CM-05, CM-07 & CM-10). We have assumed that one-quarter of all bank erosion, incision, and stream landslides are human-caused as a result of floodplain encroachment from Alpine Road, bridge crossings, modifications to stream banks, and minor increases in peak flows from roads and low-density residential development.

The above human-related contributions are crude estimates and further, detailed hydraulic analysis would be required to confirm these quantities.

4.5. Corte Madera Creek

Appendix A summarizes stream observations in Corte Madera Creek and other tributaries to Searsville Lake. Significant features of Corte Madera Creek for the sediment budget analysis are summarized below.

In Sub-subwatershed CM-12, Corte Madera Creek is constricted into a narrow channel at the toe of the Alpine Road Slide. Here, landslide movements, combined with bank erosion and channel incision of about 5 feet, are an important source of sediment. Downstream, the channel appears to exhibit two or three knickpoints; one is just upstream of Alpine Road where a local landowner has dumped concrete blocks to slow channel erosion. Corte Madera Creek shows evidence of long-term incision between the Alpine Road slide and Alpine Road but minor incision appears to have occurred recently.

Recent channel adjustments are also apparent along Corte Madera Creek just downstream of Alpine Road. In this step-pool channel section, channel incision of about 5 feet appears to have occurred over the past several decades, as indicated by degradation observed downstream of the Alpine Road culvert. Steep, high banks, abandoned overflow channels, and exposures of tree roots also indicate recent incision and widening of about one or two feet through this section. The boulder steps are steep here, formed of conglomerate boulders that are typically about 500 mm in diameter. The steps rest on soft bedrock and appear to fail by toe scour during large floods. The pools between the steps are filled with sand and gravel up to 50 mm diameter and about 0.5 to 1 foot deep. The boulder steps appear to be stable during most floods but the sediment stored in the pools appears to move frequently. Rapid incision likely occurs when the boulder steps fail, resulting in general lowering of the channel bed. Such movement may occur only every 20 years or more.

This recently incised section seems to only extend a 1,000 feet or so downstream. The next site with significant local incision is at the road bridge leading to Skyline Ridge, downstream of Damiani Creek, where coarse sediment transport may have been interrupted by the debris fan at its mouth (see following paragraphs).

Some aggrading sections are also noted along the channel, often near tributary fans. A debris flow fan at the mouth of Damiani Creek has filled a wide section of the Corte Madera Creek channel with 6 to 8 feet of coarse sediment, formed behind a logjam at the face of the deposit. Coarse sediments have also accumulated upstream of this fan; Corte Madera Creek is now incising a channel through these sediments.

Floodplains are narrow and fragmentary along Corte Madera Creek through CM-07 and CM-05 and the fill for Alpine Road encroaches on part of the floodplain, narrowing it further, and into the channel at some sites. Various protective works have been constructed along Alpine Road to prevent erosion of the road prism by the stream. These may contribute to channel incision and bank attack at some sites.

Downstream of the bridge to Skyline Ridge there is little evidence of recent incision; however terraces along the stream channel indicate long-term incision. Typically, the channel bed consists of cobble riffles with pools that are filled or partly filled by deposits of sand and fine gravel. Some the riffles are also filled with sand and gravel. These finer sediments are frequently mobile, moving over the stable, coarser bed material. Bed aggradation appears to be the dominant process by Willowbrook Drive, and here the creek is developing a sinuous pattern around bars and other sediment deposits. Bank erosion is an important process through Portola Valley and sub-subwatersheds CM-02 and CM-01, primarily occurring at the apices of bends (Cotton Shires & Associates 2001). Protective works extend along about 28% of the creek banks; with much of these works constructed since 1984 and many constructed after the 1998 flood. Many of the bank protection structures, particularly gabion baskets, are distressed and fail during large storms. Failure of gabion mats placed beneath bridges as result of flow constriction has resulted in incision and headcut migration up Corte Madera Creek.

4.6. Sediment Budget 1995 to 2000

RECONCILIATION

The measured deposition in Searsville Lake and on the Corte Madera fan from 1995 to 2000, adjusted for losses over the Searsville Dam (Table 4-1), provides an opportunity to roughly confirm the erosion estimated from sediment sources (Table 4-2). Table 4-4 adjusts the two volume estimates to weights based on densities appropriate for the different stream deposits and an assumed average density for the eroded colluvial and fluvial sediments.

Table 4-4: Reconciliation of Searsville Lake Sediment Budget, 1995 to 2000

	Total Volume (yd^3)	*Estimated Density ($tons/yd^3$)*	*Total Weight (tons)*
Erosion adjusted for Instream Deposition	305,000	1.4	427,000
Deposition in Reservoir and on Fan	349,000	1.25 on fan; 1.0 in reservoir	384,000

Table 4-4 suggests that erosion may have been overestimated, likely resulting from incorrect estimates of the average depth of landslides or other small errors in erosion rates adopted for the dominant processes. Given that the two values correspond reasonably closely, and the broad uncertainty surrounding the erosion estimates, the procedures for estimating erosion from the different sources were not adjusted.

The total erosion is divided into roughly three-quarters sand and coarser sediment and one-quarter silt and clay (Table 4-2). This breakdown is coarser than that estimated from sediment gaging at Westridge Road (Section 4.1).

RELATIVE IMPORTANCE OF EROSION SOURCES

Table 4-2 summarizes sources of sediment production in the Searsville Lake watershed for 1995 to 2000, a period of unusually high sediment yield, associated with a very large flood in 1998. Erosion was divided into three main types: landslides, streams and surface processes. Landslides, particularly small landslides adjacent to stream channels, account for about 87% of the total erosion, the overwhelming majority for the 1995 to 2000 period. Stream and surface processes erosion account for about 9% and 4%, respectively, of total erosion. As discussed earlier, the small landslides partly result from stream incision, toe undercutting, and fluvial removal of talus and consequently their contribution may partly be a result of stream channel adjustments during the large flood.

Human-caused erosion in the Searsville Lake watershed from 1995 to 2000 accounted for an estimated 16% of the total erosion and represents the erosion from direct impacts, such as man-related landslides and road erosion as well as from indirect impacts from modifications to stream hydrology or encroachments on streams and floodplains (Appendix B). Landslides and stream erosion are also the most significant sources of human-caused erosion. The sediments from human-caused erosion are slightly finer than the total erosion because of the larger role of surface erosion in environments that are human modified. Note that the estimates of human contributions from surface erosion and from indirect impacts are only rough approximations. It would require detailed investigations to accurately estimate the component that is natural and that which is human-caused.

SIGNIFICANT SOURCE AREAS

Corte Madera Creek is overwhelmingly the largest sediment producer in the Searsville Lake watershed, accounting for 78% of total erosion (Appendix B). Sediment yield from Alambique, Sausal, and Martin Creeks account for 8.4%, 7.0%, and 6.0% of total yield, respectively. Westridge Creek and other small creeks on the east side of Searsville Lake (SL-1 and SL-2) account for only 0.7% of the total sediment yield. Table 4-5 ranks sub-subwatersheds based on their natural and human-related erosion per unit area, unadjusted for deposition.

Table 4-5. Natural and Human-Related Erosion Per Unit Area by Sub-subwatershed in the Searsville Lake Subwatershed

Sub-Subwatershed	Area (acres)	Natural Erosion		Human-Related Erosion	
		Unit Erosion (yd^3/acre)	Rank	Unit Erosion (yd^3/acre)	Rank
CM-12	560	159	1	52	1
CM-7	337	82	2	16	2
CM-6	283	79	3	0.4	17
CM-5	251	47	4	11	3
CM-11	357	44	5	0.6	14
CM-9	237	35	6	0.4	20
SC-2	409	26	7	6.4	4
CM-3	378	29	8	0.4	19
CM-4	361	24	9	0.6	15
MC-1	790	18	10	5.7	5
AC-1	1492	17	11	0.8	10
SC-4	231	17	12	0.5	16
SC-5	280	15	13	0.4	21
CM-8	117	14	14	0.3	22
CM-10	86	13	15	4.7	6
CM-2	589	6	16	2.3	7
CM-1	811	4	17	1.6	8
SL-1	523	3	18	0.7	11
SC-1	381	1	19	0.6	13
SC-6	107	0.7	20	1.0	9
SL-2	556	0.3	21	0.4	18
SC-3	138	0.2	22	0.7	12
Total	9274	Mean = 29		Mean = 5.5	

A small number of sub-subwatersheds account for much of the sediment production in the watershed. Sub-subwatersheds CM-12 and CM-7 are by far the most important sediment source areas, producing about 50% of the total sediment yield in the Searsville

Lake watershed (Appendix B). Both these sub-subwatersheds contain large number of small and large landslides and the numbers of landslides in the various sub-subwatersheds largely determine their natural erosion rank. The 10 sub-subwatersheds with the highest erosion per unit area account for 86% of total sediment production whereas the bottom 10 sub-subwatersheds account for only 4.6% of total production.

Eight of the sub-subwatersheds with the greatest erosion per unit area in Table 4-5 are located in the Corte Madera Creek subwatershed, an observation in agreement with others (see Figures 6 and 7; also Kittleson *et al* 1996; Frey 2001; **nhc** *et al* 2002). Frey (2001) reported that about 40% of the streams in the Corte Madera subwatershed exhibit high sediment production whereas in Alambique, Martin, and Sausal Creeks only 19%, 11%, and 12% of the streams fall into the high sediment production category.

Natural and human-related erosion per unit area are illustrated in Figures 6 and 7. Both figures show some clear trends in sediment production. First, the greatest natural sediment producing sub-subwatersheds are located in the southern part of Corte Madera Creek, which is characterized by steep slopes, frequent landslides, erosive (Santa Clara Formation) geology, and high rates of instream erosion. These watersheds also show some of the greater human-related erosion per unit area. Watersheds with low natural erosion ranks are located in areas of low slopes – such as Portola Valley – and exhibit little or no landslide activity, and little or no instream erosion. Figure 8 shows human-related erosion as a percentage of total erosion, indicating where significant contributions from human activities occur.

4.7. Longer-Term Sediment Budgets

Rates of sediment deposition in Searsville Lake have varied widely over the 108-year period measurements, with the periods from 1892 to 1913 and 1995 to 2000 being unusually high, apparently as a result of extreme floods (Table 4-1). Deposition in the reservoir over from 1995 to 2000 averages about three and one-half times the long-term average rate and may actually be even greater, given the deposition on the fan of Corte Madera and other creeks from 1995 to 2000.

Both the total and relative contributions from the components of the sediment budget are expected to be different for long-term average rates and when sediment production is much lower. Table 4-5 summarizes our understanding of the importance of the main erosion processes during periods of very high erosion and transport (1996 to 2000), low erosion and transport (1913 to 1929) and on average (1892 to 2000), as constrained by the measured deposition in Searsville Lake. Italicized values show our estimated ranges of annual erosion for the different processes.

Surface erosion processes tend to be chronic – occurring in most years and during most storms – and their overall annual rate may not change greatly from one period to another, remaining similar to their average rates. Consequently, we have assumed that long-term average rates would be similar to those estimated for 1995 to 2000; during dry periods, the contribution would be less but not too much less. Bank erosion and channel incision are also chronic and they are thought to continue during all periods, although at significantly reduced rates during dry periods when few floods occur.

Table 4-6. Simplified Searsville Lake Sediment Budget Over Three Different Time Periods

Sediment Source	***Annual Erosion (yd^3) from*** [1]		
	1995-2000	*1892-2000*	*1914-1929*
Surface Processes	2,500	*1,500 to 2,500*	*1,000 to 1,500*
Stream Erosion	5,600	*1,000 to 3,000*	*0 to 1,000*
Landslide Processes			
- Streambank landslides	36,000	*4,000 to 8,000*	*0 to 1,000*
- Landslides from slopes	20,000	*5,000 to 15,000*	*2,500 to 5,000*
Instream Deposition	(2,300)	*+500 to –500*	*+500 to –500*
Average Annual Transport to Searsville Lake [1]	62,000	17,000 [2]	6,500 [2]

1. From Table 4-1 or 4-2. Italicized numbers are rough estimates.
2. Deposition in reservoir only; underestimates annual transport.

Landslides are by far the dominant erosion process from 1995 to 2000 but the rates observed during this period are not sustained over the long-term and must be dramatically less just to balance the observed deposition in Searsville Lake. Abundant landsliding from slopes is known to have occurred frequently over the past 150 years, averaging about once every five years or so (**nhc** and JSA 2003a). The air photo inventory reported in **nhc** and JSA (2003a) suggests that average area disturbed by landslides over the past thirty to forty years is roughly half of that observed from 1995 to 2000 and we have assumed that long-term erosion from landslides originating on slopes is from one-quarter to three-quarters of the rate observed from 1995 to 2000. During dry periods, when large storms rarely occur, this rate declines much further. Although rare, major earthquakes caused widespread landsliding in the Searsville Lake watershed in 1906 and are a significant contributor to long-term landslide erosion.

Very large adjustments are thought to occur in the streamside landslides from one time period to the next. While they are the dominant source from 1995 to 2000, such rates of erosion cannot be sustained because slope processes do not provide sediment to the stream margins at high enough rates. These landslides seem to be driven by channel incision, widening, and other adjustments that occurs as a result of bed mobilization during extreme floods, as indicated by the correlation of high sediment yield periods with extreme floods (Section 2.2). As a corollary, large numbers of streambank landslides are very unlikely to occur during periods of low peak flows and they may be much less important to the long-term average sediment budget because of their infrequent occurrence. We have assumed that large numbers of the streamside landslides occur every fifty years or so, yielding long term rates that are about one-tenth to one-fifth of the erosion rate observed from 1996 to 2000. These landslides are assumed to occur very infrequently during dry periods when sediment transport is low.

During the different time periods, different processes become important, which have consequences for management. Over the long-term, landslides originating on slopes away from streams seem to be the dominant erosion process; surface erosion is also more important than it might appear based on the 1995 to 2000 budget. During periods of relatively low sediment production, such as occurred from 1914 to 1929, surface erosion may even be the dominant erosion process.

As discussed earlier, human modifications of Searsville watershed are responsible for about 16% of the total erosion from 1995 to 2000. Over the past 100 years, human impacts are mostly from surface erosion from roads and developments and landslides initiating at roads – hydromodification is assumed to be less significant than over the past five years. The greater length of unpaved roads in the past may actually have increased yields from surface erosion, particularly along Alpine Road where cut bank and fill slope erosion appear to have been important sediment processes in the past. Assuming that human modification is responsible for about one-third to one-half of the surface erosion and about one-third of the erosion from large landslides (see **nhc** and JSA 2003a; their Table 7), then it contributes between 12% and 37% of the long-term average erosion.

5. LOS TRANCOS SEDIMENT BUDGET

5.1. Approach

Los Trancos Watershed lies south of Searsville Lake Watershed and joins San Francisquito Creek near Junipero Serra Boulevard, from the southwest (Figure 1). Los Trancos Watershed includes seven subwatersheds and has an area of about 7.6 mi^2.

Los Trancos has detailed sediment transport measurements from 1995 to 2001 and longer-term measurements based on applying sediment rating curves to simulated discharges (see **nhc** *et al* 2002). The substantial database regarding erosion that is available for the Searsville Lake Watershed is not available for either Los Trancos Creek. Consequently, the overall budget here is much less detailed. The budget is not closed nor verified with the sediment transport estimates as in the previous section, rather sediment transport is used to balance erosion and estimate missing quantities.

However, the purpose of the budget analysis is the same as for Searsville Lake: to identify those areas that are most important to sediment production, estimate the relative importance of different sediment sources to total yield, and estimate the contribution of human activities to erosion, particularly from 1995 to 2000.

5.2. Sediment Transport

Owens, Chartrand and Hecht (2002) summarize the results of their flow and sediment gaging on Los Trancos Creek, for the water years from 1995 to 2001. Annual suspended loads were not measured in 1995 or 1996, but bed loads were. Based on the observed loads in other years, it is likely that suspended transport is about 1,000 tons in 1996.

For WY 1996 to 2000, their gaging program shows a suspended load of 10,000 tons (8,700 yd^3; assuming 1.15 tons/yd^3) and a bed load of 10,400 tons (8,300 yd^3; assuming 1.25 tons/yd^3), for a total of 17,000 yd^3, or an annual average of 3,400 yd^3. The bedload is assumed to consist entirely of sand and coarser sediment. No particle size distributions are available for the suspended load, so we have assumed that it is one-third sand and two-thirds silt and clay. On this basis, the total load is divided into just less than two-thirds coarse material (sand, gravel and cobbles) and about one-third fine sediment (silt and clay). The estimated coarse load includes quantities of fine sand that are not found in the streambed in large quantities and are not part of the proper bed material load.

Long-term sediment yields (1964 to 2002) were calculated by applying the suspended sediment rating curve to simulated flows and from bed material transport calculated from the calibrated HEC-6 model (**nhc** et al 2002). The long-term loads are about 44% of those for WY 1996 to 2000, or about 1,500 yd^3. Coarse sediment is assumed to be half or more of the long-term total. As discussed in Sections 6 and 7 the above estimate of the long-term load likely underestimates the average contribution to San Francisquito Creek.

5.3. Sediment Sources

OVERVIEW

Sediment sources in the Los Trancos watershed that contribute to streams can be divided into two broad categories; discrete sources, such as landslides and gully erosion, and diffuse sources, such as bank erosion, sheetwash or surface erosion, and other hillslope erosion processes. The nature of each source, how we identified them in the watershed, and the estimated rates of erosion for the 1995 to 2000 period followed the procedures adopted for Searsville Lake Watershed, with the exceptions described below. Table 5-1 summarizes erosion volumes contributed to streams between 1995 and 2000 and indicate the range of uncertainty in these estimates and the likely grain sizes of the erosion products.

LANDSLIDES

No measurements of the area or volume of sediment contributed by streamside landslides in Los Trancos Watershed are available. We attempted to correlate the small landslide volumes for in Searsville Lake Watershed to the erosivity index described below and to other physical characteristics of the sub-subwatersheds. However, we were unable to construct a satisfactory predictive relationship in the Searsville Watershed that could be applied to the Los Trancos sub-subwatersheds. Instead, we estimated the volume of streamside landslides by balancing erosion and sediment transport, calculating the small landslide contribution as the remainder. Estimated erosion was about equal to transport in Los Trancos and the volume from small and large streamside landslides was arbitrarily set to zero. This was consistent with field observations of the main channel of Los Trancos Creek. We saw no evidence of small landslides entering the creek from steep lower valley slopes, which are mostly distant from the creek. However, streamside landslides may be more important in steep channels in the upper watershed.

STREAM EROSION

We also did not have any information on where bank erosion occurred in Los Trancos watershed or the severity of the erosion that occurred. To correct this deficiency, we correlated the percentage stream length with severe or moderate bank erosion observed in Searsville Lake Watershed to an erosivity index constructed by adding the percentages of erosive geology, stream length with erosive slope, and stream length near a landslide zone listed in the sub-subwatershed characteristics included in the Historic Conditions Memorandum. The relationships showed reasonably high correlations and they were applied to estimate the percent severe and moderate in the sub-subwatersheds in the sub-subwatersheds. Once the eroding bank lengths were predicted, erosion volumes were calculated as described previously (Appendix C).

The extent of channel incision was based on existing reports and field inspections (Section 5.5 provides further details). We observed no recent incision along Los Trancos Creek, other than its lowest 500 feet or so (Appendix A). One small tributary to Los Trancos Creek in Los Trancos Woods (LT-06) showed one or two feet of recent incision that is included in the gully erosion estimates.

STREAM DEPOSITION

The volumes of coarse sediment deposited along Los Trancos Creek and its tributaries were estimated from existing reports and field observations. We observed accumulation of cobble, gravel and sand along much of Los Trancos Creek in LT-03, LT-04 and LT-06. Deposition volumes were estimated by assuming that deposition averaged 0.25 feet over the stream bottom over about half of the stream length in each of these sub-subwatersheds. Deposition is also reported in a marsh or wetland in Buckeye Creek (LT-05); however, we did not inspect this creek to confirm if this occurs and have not included this area is our total.

Table 5-1: Total Erosion and Erosion by Grain Size Contributed to Streams in Los Trancos Watershed from 1995 to 2000

Sediment Source	*Total Erosion (yd^3)*	*Likely Range (%)*	*Comment*	*Coarse Sediment (yd^3)* [1]	*Fine Sediment (yd^3)* [1]
Small streamside	0		Set to zero	0	0
Large streamside	0		Set to zero	0	0
Hillslope landslides	12,400	±25%	Depth uncertain	9,000	3,400
Bank Erosion	2,100	±50%	Unit volume and extent uncertain	1,400	700
Channel Incision	0	±50%	Set to zero	0	0
Road Erosion	1,300	±75%	Likely overestimated	400	900
Scar/Scarp Erosion	100	±75%	Rough estimate	0	100
Sheet Erosion	300	±75%	Rough estimate	0	300
Gully Erosion	2,000	±75%	Length and volume uncertain	1,000	1,000
Totals	***18,200***	***12,000 to 24,000***		***11,800***	***6,400***

2. Coarse sediment is sand and larger (>0.063 mm); fine sediment is silt and clay (<0.063 mm).

4.4. Human Contributions to Erosion

Human contributions to erosion resulting from direct and indirect (hydromodification) alterations of natural processes are summarized in Table 5-2. Direct contributions include:

- Landslides on slopes that appear to originate at roads, developments or areas disturbed by human activity
- Surface erosion of landslide scars that result from human activity
- Surface erosion from roads, and
- Surface erosion from grasslands or disturbed soils

- Gullies erosion attributed to human disturbance. As in the previous section we have assumed that about one-third of the total volume results from human disturbance.

Indirect contributions include bank erosion, channel incision, and streamside landslides that may result from increased peak flows from development. Bank erosion or streamside landslides that may result from encroachment onto floodplains or streams or human modification of stream banks are also included. It is our view that development has little or no effect on peak flows and, consequently, little or no effect on bank erosion. However, banks have been modified to some extent by development, as follows (Table 5-2; see also Appendix C):

- Los Trancos Creek (LT-03, LT-04, LT-06). We have assumed that one-quarter of all bank erosion is human-related, as a result of modifications to stream banks from low-density residential development and roads.

The above human-related contribution is a crude estimates and further, detailed hydraulic analysis would be required to confirm these quantities.

Table 5-2: Human-Related Total Erosion and Erosion by Grain Size Contributed to Streams in Los Trancos Watershed from 1995 to 2000

Sediment Source	*Total Erosion* (yd^3)	*Likely Range (%)*	*Comment*	*Coarse Sediment* $(yd^3)^1$	*Fine Sediment* $(yd^3)^1$
Direct Contributions					
Hillslope landslides	4,200	±25%	Depth uncertain	3,000	1,200
Road Erosion	1,300	±75%	Likely overestimated	400	900
Scar/Scarp Erosion	100	±75%	Rough estimate	0	100
Sheet Erosion	300	±75%	Rough estimate	0	300
Gully Erosion	600	±75%	Human impact very uncertain	300	300
Indirect Contributions (Hydromodification)					
Bank Erosion and Channel Incision	200	±50%	Human impact uncertain	150	50
Small streamside	0		Set to zero	0	0
Totals	***6,700***	***3,800 to 9,900***		***3,900***	***2,800***

2. Coarse sediment is sand and larger (>0.063 mm); fine sediment is silt and clay (<0.063 mm).

5.5. Los Trancos Creek

Los Trancos Creek has a steep reach, incised into bedrock, in the first 500 feet upstream of San Francisquito Creek. This reach is thought to be degrading or incising in response to adjustments in San Francisquito Creek. Incision does not yet seem to have progressed past the small weir at the head of this section.

Further upstream, through LT-03, LT-04 and the lower part of LT-06, Los Trancos Creek flows in moderately broad valley and is seldom in contact with its valley walls. No small landslides into the creek were observed during a brief inspection. The channel appeared to have stored coarse sediment and sand on bars and along the streambed following the 1998 storm and to move these sediments frequently (Appendix A). Gullies, and gully failures, along the steep left (west) valley wall appear to an important sediment source, however, we observed no evidence of recent failures in these gullies.

5.6. Sediment Budget from 1995 to 2000

RECONCILIATION

As noted earlier, the difference between estimated erosion and transport volumes from 1995 to 2000 was used to estimate the contribution from small landslides, so the transport estimates do not actually reconcile the budget. Table 5-3 adjusts the erosion and transport estimates to weights based on appropriate densities.

Table 5-3: Reconciliation of the Los Trancos Sediment Budget, 1995 to 2000

	Total Volume (yd^3)	*Estimated Density ($tons/yd^3$)*	*Total Weight (tons)*
Erosion adjusted for Instream Deposition	16,400	1.40	23,000
Estimated Transport at Westridge gage	17,000	1.25 or 1.15	20,400

Table 5-3 suggests that estimated erosion is reasonably consistent with measured transport, assuming that small streamside landslides do not contribute to the overall erosion. Given that the two values correspond reasonably closely, and the broad uncertainty surrounding the erosion estimates, the procedures for estimating erosion from the different sources were not adjusted.

The total erosion is divided into roughly two-thirds sand and coarser sediment and one-third silt and clay (Table 4-1). This breakdown is coarser than that that estimated for the sediment transport reported at the Arastradero Road gage (Section 5.2).

RELATIVE IMPORTANCE OF EROSION SOURCES

Table 5-1 summarizes the sources of erosion in the Los Trancos watershed for 1995 to 2000, a period of unusually high sediment yield that includes the very large flood in 1998. Landslides on slopes account for 68% of the total erosion; stream and surface processes erosion account for about 12% and 20%, respectively, of total erosion.

Human-caused erosion in the Los Trancos watershed from 1995 to 2000 accounted for an estimated 37% of the total, mostly from direct impacts, such as human-related landslides and road and gully erosion (Appendix C). Landslides are also the most significant sources of human-caused erosion. The sediments from human-caused erosion are slightly finer than the total erosion because of the larger role of surface erosion in environments that are human modified. Note that the estimates of human contributions from surface erosion and from indirect impacts are only rough approximations. It would require detailed investigations to accurately estimate the component that is natural and that which is human-caused. Figure 8 shows human-related erosion as a percentage of total erosion, indicating those areas where human modifications are significant.

SIGNIFICANT SOURCE AREAS

About half of the total erosion occurs in sub-subwatershed LT-06 and the three sub-subwatersheds that extend to upper Los Trancos (LT-05, LT-06 and LT-07) include nearly all the erosion. Table 5-4 ranks the sub-subwatersheds based on their natural and human-related erosion per unit area, unadjusted for deposition.

Table 5-4: Natural and Human-Related Erosion Per Unit Area by Sub-subwatershed in Los Trancos Watershed

Sub-Subwatershed	Area (acres)	Natural Erosion		Human-Related Erosion	
		Unit Erosion (yd^3/acre)	Rank	Unit Erosion (yd^3/acre)	Rank
LT-06	1,000	4.9	1	4.2	1
LT-07	807	3.9	2	0.5	5
LT-05	920	2.6	3	0.5	3
LT-01	405	0.77	4	0.4	6
LT-02	555	0.71	5	0.3	7
LT-03	534	0.47	6	0.5	4
LT-04	649	0.43	7	1.5	2
Total	4,870	Mean = 2.4		Mean = 1.4	

Most of the human-related erosion also occurs in LT-06, although the sub-subwatersheds are ranked differently, with LT-04 also a significant contributor (Appendix C). Natural and human-related erosion per unit area are also illustrated in Figures 6 and 7. Both figures show some clear trends in sediment production. First, the greatest natural sediment producing sub-subwatersheds are in upper Los Trancos Creek, which is characterized by steep slopes and erosive geologies, adjacent to upper Corte Madera Creek. Note that unit erosion rates are substantially lower than in the nearby sub-subwatersheds of upper Corte Madera Creek.

5.6. Longer-Term Sediment Budgets

Rates of erosion and transport in Los Trancos are thought to be highly variable, and transport rates from 1995 to 2000 are much higher than the long-term averages. Table 5-5 summarizes our understanding of the importance of the different erosion processes during 1995 to 2000 compared to the average estimated for 1964 to 2002.

As discussed in detail for the Searsville Lake budget, surface erosion processes tend to be chronic – occurring in most years and during most storms – and their overall annual rate may not change greatly from one period to another. Consequently, we have assumed that long-term average rates would be similar to those estimated for 1995 to 2000. Gully and bank erosion are also chronic, although they proceed at much lower rates over the long-term.

Table 5-5: Simplified Los Trancos Sediment Budget Over Two Different Time Periods

Sediment Source	***Annual Erosion (yd^3) Over*** [1]	
	1995-2000	*1964-2002*
Surface Processes	300	*100 to 200*
Gully Erosion	400	*100 to 200*
Stream Erosion	400	*100 to 200*
Landslide Processes		
- Streambank landslides	0	*0 to 200*
- Landslides from slopes	2,500	*700 to 1,200*
Instream Deposition	(400)	*0*
Average Annual Transport to San Francisquito Creek [1]	3,300	1,500

1. From Table 4-1 or 4-2. Italicized numbers are rough estimates.

Landslides are by far the dominant erosion process from 1995 to 2000. Abundant landsliding from slopes is known to have occurred frequently over the past 150 years, averaging about once every five years or so (**nhc** and JSA 2003a). The air photo inventory reported in **nhc** and JSA (2003a) suggests that average area disturbed by landslides over the past thirty to forty years is roughly half of that observed from 1995 to 2000 and we have assumed that long-term erosion from landslides originating on slopes to streams is from one-quarter to one-half of the rate observed from 1995 to 2000.

Landsliding on slopes seems to be the dominant process over 1995 to 2000 and also over the long-term. In Los Trancos watershed, human impacts on slope stability are probably the most significant factor in increasing erosion and the most important consideration for sediment management. Surface erosion processes are relatively unimportant, both over the short-term and long-term.

6. BEAR SEDIMENT BUDGET

6.1. Approach

Bear Creek lies north of Searsville Lake Watershed and joins San Francisquito Creek just below Searsville Dam (Figure 1). The Bear Watershed includes the Bear Creek, Bear Gulch and West Union Creek subwatersheds and has a total area of about 11.6 mi^2.

Bear Creek has only a few miscellaneous sediment transport measurements. Sediment transport from 1995 to 2000 and over the longer-term has been estimated by applying sediment rating curves to simulated flows and adjusting measured loads from the Los Trancos gage (**nhc** *et al* 2002). The substantial database regarding erosion that is available for the Searsville Lake Watershed is not available for Bear Creek and the overall budget here is much less detailed. The budget is neither closed nor verified with the sediment transport estimates, rather sediment transport is used to balance erosion and estimate missing quantities.

However, the purpose of the budget analysis is the same as for Searsville Lake: to identify those areas that are most important to sediment production, and estimate the relative importance of different sediment sources to total yield, and estimate the contribution of human activities to erosion, particularly from 1995 to 2000.

6.2. Sediment Transport

Only occasional suspended and bed load measurements have been collected on Bear Creek. Based on applying sediment rating curves to simulated flows, bed load transport in Bear Creek is just over one-third of that in Los Trancos and suspended sediment transport is about 3.5 times greater than from Los Trancos Creek (see **nhc** et al 2002). On this basis, bed load transport from 1995 to 2000 is estimated to be 3,300 yd^3; suspended load transport is estimated to be 30,000 yd^3. Average annual load is then 6,700 yd^3.

Assuming that the bedload is sand and gravel and that the suspended load is one-third sand and two-thirds silt and clay, the total load from 1995 to 2000 is divided into 13,300 yd^3 of coarse sediment and 20,000 yd^3 of fine sediment. The above estimates are not very accurate, but they are adequate for evaluating estimated erosion.

Long-term sediment transport (1964 to 2002) calculated by applying the suspended sediment rating curve to simulated flows and from bed material transport calculated from the calibrated HEC-6 model (**nhc** et al 2002) is about 46% of that from 1995 to 2000, or about 3,100 yd^3. Coarse sediment is assumed to be only a small portion of the long-term annual load. Combined long-term annual transport from Bear and Los Trancos amount to a little more than half of the long-term annual load estimated for the gage on San Francisquito Creek, suggesting the long-term estimates for the individual tributaries are too low (see Section 7).

6.3. Sediment Sources

OVERVIEW

Sediment sources in the Bear Creek watershed that contribute to streams can be divided into two broad categories; discrete sources, such as landslides and gully erosion, and diffuse sources, such as bank erosion, sheetwash or surface erosion, and other hillslope erosion processes. The nature of each source, how we identified them in the watershed, and the estimated rates of erosion for 1995 to 2000 followed the procedures adopted for Searsville Lake Watershed, with the exceptions described below. Table 6-1 summarizes erosion volumes contributed to streams between 1995 and 2000 and indicate the range of uncertainty in these estimates and the likely grain sizes of the erosion products.

LANDSLIDES

No measurements of the area or volume of sediment contributed by streamside landslides in Bear Watershed are available. We attempted to correlate the small landslide volumes in Searsville Lake Watershed to the erosivity index described below and to other physical characteristics of the sub-subwatersheds. However, we were unable to construct a satisfactory predictive relationship in the Searsville Watershed that could be applied to the Bear sub-subwatersheds. Instead, we estimated the volume of small landslides by roughly balancing erosion and transport volumes, calculating the small landslide contribution as the remainder. On this basis about 10,000 yd^3 was assigned to this process, distributed roughly evenly over the eight steeper sub-subwatersheds – Bear (BG-02 and 03), Appletree, Tripp, Squealer, and McGarvey Gulches and upper West Union Creek (WUC-9 and WUC-11).

STREAM EROSION

We also did not have any information on where bank erosion occurred in Bear sub-subwatersheds or the severity of the erosion that occurred. To correct this deficiency, we correlated the percentage stream length with severe or moderate bank erosion observed in Searsville Lake Watershed to an erosivity index constructed by adding the percentages of erosive geology, stream length with erosive slope, and stream length near a landslide zone listed in the sub-subwatershed characteristics included in the Historic Conditions Memorandum. The relationships showed reasonably high correlations and they were applied to estimate the percent severe and moderate bank erosion in the Bear sub-subwatersheds. Once the eroding bank lengths were predicted, erosion volumes were calculated as described previously.

Observations by Smith and Harden (2001) indicated long-term incision on Bear Creek and West Union Creek but they identified no evidence of recent incision (see Section 6.4). However, they identified incision along Bear Gulch downstream of the CalWater diversion (BG-01 and much of BG-02) as a result of interception and removal of coarse material load. We have assumed that incision of about one foot occurred along half of the stream channel in these two sub-watersheds from 1995 to 2000 (Appendix C).

STREAM DEPOSITION

Volumes of coarse sediment deposited along Bear Creek and its tributaries were estimated from existing reports and field observations. Smith and Harden (2001) reported sporadic accumulation of sand and fine sediment along Bear Creek and West Union Creek. We have assumed that deposition covers about one-quarter of the length of stream in BC-01, BG-01, BC-02, WUC-03, WUC-05 and WUC-07 to a depth of about 0.25 feet. Some deposition likely also has occurred in the steep upper tributaries but it is not included in our sediment sources.

Table 6-1: Total Erosion and Erosion by Grain Size Contributed to Streams in Bear Watershed from 1995 to 2000

Sediment Source	*Total Erosion (yd^3)*	*Likely Range (%)*	*Comment*	*Coarse Sediment (yd^3) [1]*	*Fine Sediment (yd^3) [1]*
Small streamside	9,900	±50%	Estimated volume	6,600	3,300
Large streamside	0	±75%	Not estimated	0	0
Hillslope landslides	600	±25%	Depth uncertain	400	200
Bank Erosion	12,700	±50%	Unit volume uncertain	9,000	3,700
Channel Incision	2,000	±50%	Depth uncertain	1,600	400
Road Erosion	1,800	±75%	Likely overestimated	400	1,400
Scar/Scarp Erosion	200	±75%	Rough estimate	0	200
Sheet Erosion	500	±75%	Rough estimate	0	500
Gully Erosion	2,900	±75%	Length and volume uncertain	1,000	1,900
Totals	***30,600***	***13,000 to 47,000***		***19,000***	***11,600***

3. Coarse sediment is sand and larger (>0.063 mm); fine sediment is silt and clay (<0.063 mm).

6.4 Human Contributions to Erosion

Human contributions to erosion as a result of both direct and indirect (hydromodification) alterations of natural processes are summarized in Table 6-2. Direct contributions include:

- Landslides on slopes that appear to originate at roads, developments or areas disturbed by human activity
- Surface erosion of landslide scars that result from human activity
- Surface erosion from roads, and
- Surface erosion from grasslands or disturbed soils
- Gullies erosion attributed to human disturbance (We have assumed that one-third of the total erosion volume is human-related, as in previous sections.)

Indirect contributions include bank erosion, channel incision, and landslides along streams that may result from increased peak flows from development or bank erosion or landslides along streams that may result from encroachment onto floodplains or streams or human modification of stream banks. We have assumed that development has not modified hydrographs in Bear Creek or its tributaries but that development in the floodplain and modification of stream banks has contributed to bank erosion in the following sub-subwatershed (see Appendix C):

- Bear Creek (BC-01 and BC-02). We have assumed that one-quarter of all bank erosion results from modifications to stream banks from low-density residential development, bridges and roads.
- Bear Gulch (BG-01 and BG-02). We have assumed that one-quarter of all bank erosion in BG-01 results from modifications to stream banks from low-density residential development, bridges and roads. Incision in these two sub-subwatersheds is assumed to result entirely from human modifications.
- West Union Creek (WUC-01, WUC-03 and WUC-05). We have assumed that one-quarter of all bank erosion results from modifications to stream banks from low-density residential development, bridges and roads.

The above human-related contributions are crude estimates and further, detailed hydraulic analysis would be required to confirm these quantities.

Table 6-2: Human-Related Total Erosion and Erosion by Grain Size Contributed to Streams in Bear Watershed from 1995 to 2000

Sediment Source	*Total Erosion (yd^3)*	*Likely Range (%)*	*Comment*	*Coarse Sediment (yd^3)* [1]	*Fine Sediment (yd^3)* [1]
Direct Contributions					
Hillslope landslides	0			0	0
Road Erosion	1,800	±75%	Likely overestimated	400	1,400
Scar/Scarp Erosion	0			0	0
Sheet Erosion	500	±75%	Rough estimate	0	500
Gully Erosion	600	±75%	Human impact very uncertain	300	300
Indirect Contributions (Hydromodification)					
Bank Erosion and Channel Incision	2,300	±50%	Human impact uncertain	1,700	600
Small streamside	0		Human impact uncertain	0	0
Totals	***5,200***	***1,900 to 8,500***		***2,400***	***2,800***

2. Coarse sediment is sand and larger (>0.063 mm); fine sediment is silt and clay (<0.063 mm).

6.5. Bear, Bear Gulch and West Union Creeks

Smith and Harden (2001) describe the reaches of Bear Creek and West Union Creek that lie along the San Andreas Fault Zone and Bear Gulch. They found an entrenched channel with relatively stable banks, with bedrock exposed in the bed for several miles upstream of the mouth. Bank protection, consisting of riprap, gabions or concrete cribbing, has been placed along sections of the stream, primarily on lower West Union Creek, presumably where erosion has occurred in the past.

Smith and Harden identify a number of concrete diversion dams and other structures along Bear and West Union Creeks as part of their assessment of fish passage. Most of these structures show some evidence of incision downstream and filling upstream of the structures. Incision appears to be typically a few feet at the structures and to extend along most of Bear and West Union Creeks. The period over which this incision occurred is not known but is expected to be several decades and little of the incision appears recent, based on examining site photographs. Significant incision is also observed on Bear Gulch at Highway 84. Removal of coarse sediment that accumulates at the water supply diversion dam reduces coarse be load sediments and contributes to the incision.

One of the more interesting observations by Smith and Harden is the presence of an 11-foot high falls in West Union Creek, upstream of Huddart Park. They identify this as a knickpoint that developed from displacement along the San Andreas Fault Zone during the 1906 San Francisco Earthquake. It is unclear how far this knickpoint has migrated over the past 100 years, but such deep incision may have been a significant sediment source in the past and again in the future, as it migrates upstream.

6.6. Sediment Budget from 1995 to 2000

RECONCILIATION

As noted earlier, the difference between estimated erosion and transport volumes from 1995 to 2000 has been used to estimate the contribution from small landslides, so the transport estimates do not actually reconcile the budget. Table 6-3 adjusts the erosion and transport estimates to weights based on suitable densities.

Table 6-3: Reconciliation of Bear Sediment Budget, 1995 to 2000

	Total Volume (yd^3)	*Estimated Density ($tons/yd^3$)*	*Total Weight (tons)*
Erosion adjusted for Instream Deposition	30,000	1.40	42,000
Estimated Transport at Westridge gage	33,000	1.15 and 1.25	39,000

Table 6-3 suggests that estimated erosion is reasonably consistent with measured transport, assuming that contribution from small streamside landslides is accurately estimated by the difference between erosion and transport. Given the broad uncertainty surrounding the erosion and transport estimates, the procedures for estimating erosion from the different sources were not adjusted.

The total erosion is divided into a bit less than two-thirds sand and coarser sediment and a little more than one-third silt and clay (Table 6-1). This is very inconsistent with the breakdown estimated from adjusting sediment transport measures and suggests that either the sediment transport data is not accurate (Section 6.1) or that the portion of fine sediment in the erosion products has been greatly underestimated. Human-related sediment is finer than the overall erosion product.

RELATIVE IMPORTANCE OF EROSION SOURCES

Table 6-1 summarizes sources of erosion in the Bear watershed for 1995 to 2000, a period of unusually high sediment yield that includes the very large flood in 1998. Streamside landslides and landslides from slopes account for 34% of the total erosion (based on the adjustment discussed earlier); streams accounted for 48% and surface erosion for about 18% of total erosion. If the adjustment that added erosion from streamside landslides to the total budget were ignored, stream bank erosion would be by far the dominant source.

Table 6-4. Natural and Human-Related Erosion Per Unit Area by Bear Creek Sub-subwatershed

Sub-Subwatershed	Area (acres)	Natural Erosion		Human-Related Erosion	
		Unit Erosion (yd^3/acre/yr)	Rank	Unit Erosion (yd^3/acre/yr)	Rank
WUC-4	271	9.1	1	0.2	15
WUC-2	242	8.4	2	0.2	14
WUC-9	272	7.7	3	0.3	12
BG-3	583	6.4	4	0.4	11
WUC-6	528	5.2	5	0.5	9
WUC-8	543	4.4	6	0.3	6
WUC-11	875	4.2	7	0.2	13
BG-2	1,239	3.3	8	1.4	2
WUC-10	64	1.4	9	0.2	16
WUC-7	281	1.1	10	0.7	3
BG-1	428	0.9	11	2.2	1
WUC-5	192	0.8	12	0.6	7
BC-1	618	0.7	13	0.7	4
WUC-1	170	0.6	14	0.7	5
BC-2	964	0.5	15	0.6	8
WUC-3	139	0.5	16	0.4	10
Total	7,409	Mean = 3.4		Mean = 0.7	

Human-caused erosion in the Bear watershed from 1995 to 2000 accounted for an estimated 17% of the total erosion, mostly from indirect impacts on stream erosion through modification of banks, and incision related to trapping of coarse sediment at the diversion dam on Bear Gulch and roads (Appendix C). Note that the estimates of human contributions from direct and indirect impacts are only rough approximations. It would require detailed investigations to accurately estimate the component that is natural and that which is human-caused.

SIGNIFICANT SOURCE AREAS

Erosion is spread relatively evenly over the sixteen sub-subwatersheds, with the greatest erosion volumes from Bear Gulch (BG-02 and BG-03), which includes about 20% of all erosion (Figures 6 and 7). Natural erosion contributions are greatest from the steep tributaries that extend into the Santa Cruz Mountains (see Table 6-4). The sub-subwatersheds that lie along the main streams and in the valley of the SAFZ through Woodside typically have low natural erosion contributions per unit area. However, they have the greatest human-related erosion contributions (Figure 7) and these contributions are the greatest percentage of total erosion there (Figure 8). The greatest human -related erosion is from Bear Gulch, based on the assumed incision rates that occur because of coarse sediment diversion.

Natural and human-related erosion per unit area are also illustrated in Figures 6 and 7. Note that unit erosion rates in the tributaries in the Santa Cruz Mountains in Bear Watershed are strongly affected by the assumptions about streamside landsliding there and may not reflect the actual distribution of erosion volumes.

6.6. Longer-Term Sediment Budgets

Rates of erosion and transport in Bear Creek from 1995 to 2000 are thought to be greater than long-term averages. Table 6-5 summarizes our understanding of the importance of the main erosion processes during 1995 to 2000 compared to the average estimated for 1964 to 2002.

As discussed for the Searsville Lake budget, surface erosion processes tend to be chronic – occurring in most years and during most storms – and their overall annual rate may not change greatly from one period to another. Consequently, we have assumed that long-term average rates would be a little less than those estimated for 1995 to 2000. Gully and bank erosion are also chronic, although they proceed at much lower rates over the long-term, with stream bank erosion at about half of the rate estimated for 1995 to 2000.

Stream erosion is the dominant erosion process from 1995 to 2000 and, with landslides from slopes, may be the most significant process over the long term. Bear Watershed had unusually few landslides from slopes from 1995 to 2000. The air photo inventory reported in **nhc** and JSA (2003a) suggests that average area disturbed by landslides over the past thirty to forty years is about the same as in Los Trancos and we have assumed that long-term erosion from landslides originating on slopes in Bear Watershed is similar to the long term rate in Los Trancos. The contribution of small landslides to the long-term budget is not certain and further stream inventory would be needed to address this issue.

Table 6-5. Simplified Bear Watershed Sediment Budget Over Two Different Time Periods

Sediment Source	***Annual Erosion (yd^3) Over*** [1]	
	1995-2000	*1964-2002*
Surface Processes	500	*100 to 200*
Gully Erosion	600	*300 to 400*
Stream Erosion	3,000	*1,000 to 2,000*
Landslide Processes		
- Streambank landslides	2,000	*0 to500*
- Landslides from slopes	100	*500 to 1,500*
Instream Deposition	(200)	*0*
Average Annual Transport to San Francisquito Creek [1]	6,000	3,100

1. From Table 6-1. Italicized numbers are rough estimates.

Given that stream erosion is one of the dominant process over 1995 to 2000 and over the long-term, human impacts on stream banks, sediment transport, and watershed hydrographs are probably the most significant factors for sediment management. Gully erosion is also important and management of stormwater from roads and developments is an important component of sediment management. Other surface erosion processes are relatively unimportant, both over the short-term and long-term.

7. SAN FRANCISQUITO CREEK SEDIMENT BUDGET

7.1. Background

San Francisquito Creek is the most downstream subwatershed and it receives water and sediment from the Los Trancos, Bear and Searsville Lake subwatersheds. This subwatershed has 12 sub-subwatersheds – including the most urbanized part of San Francisquito Creek – and a total area of about 13.4 mi^2 (Figure 1).

Suspended sediment transport was measured at the USGS station at Stanford in the late 1950s and 1960s (see Porterfield 1980; Brown and Jackson 1973) and a few miscellaneous measurements were collected in the 2000 and 2001 (**nhc** *et al* 2002; Balance Hydrologics 2001). **nhc** et al (2002) provide detailed bedload transport modeling along San Francisquito Creek. However, there are no measurements of erosion in the subwatershed for recent years, although erosion estimates can be constructed for longer time periods. As for Los Trancos and Bear watersheds, the budget is not closed nor verified with the sediment transport estimates, but rather sediment transport is balanced with erosion and differences are used to estimate missing quantities.

The budget analysis is restricted to 1964 to 1998 and focuses on identifying the relative importance of different sources to total erosion, and the contribution of human activities to erosion.

6.3. Sediment Transport

Porterfield (1980) reports estimates of long-term sediment transport in San Francisquito Creek based on applying a suspended load rating curve developed from measurements at the USGS gage at the Stanford Golf Course between 1957 and 1962 to a flow duration curve at the gage (Table 7-1). Porterfield also measured the portion of sand in the suspended load, developed a separate rating for sand load, and noted that most sand appeared to be in suspension at the gage.

Brown and Jackson (1973) reported suspended sediment loads measured at the gage at Stanford University from 1962 to 1969 (Table 7-1). Balance Hydrologics, Inc (2001) subsequently measured a few suspended sediment loads in 2000 and 2001, confirmed no gross changes in their sediment rating curve, and recommended an equation relating sediment discharge and stream flow. Application of their equation to the daily flows recorded from 1964 to 1998, predicts an annual suspended sediment transport of 12,000 tons (9,600 yd^3, assuming 1.25 tons/yd^3), nearly the same as the long-term load estimated by Porterfield. Grain size distributions of the suspended load are not reported, but it is reasonable to assume that sand forms a significant component of the suspended load in the steep reach at the gage site.

Annual suspended sediment discharges for 1962 to 1969 are reported by Brown and Jackson (1973) and included in the Historic Conditions Memorandum (see Table 7-1). They show that annual suspended load varied from 1,100 to 50,600 tons, with the greatest transport during years with large peak flows.

nhc et al (2002) estimated wash load (silt and clay) transport for current conditions as part of their HEC-6 sediment transport model. The wash load, which includes overflow from Searsville Dam and contributions from Los Trancos and Bear Creek as well as other sources, appear to average about 4,000 tons per year. This suggests that about two-thirds of the average suspended load is sand; about one-third is silt and clay. This is about twice as great as that measured by Porterfield (1980).

Table 7-1: Suspended Sediment Transport Measurements in San Francisquito Creek

Source	*Period*	*Annual Suspended Load (yd^3)* [1]		
		Total	Sand	Silt and Clay
Porterfield (1980)	1909-1966	9,000	3,000	6,000
	1957-1959	13,000	4,000	9,000
	1957-1966	6,700	-	-
Brown and Jackson (1973)	1962-1969	12,000	-	-
	1964-1998	9,600	-	-

1. Assumes 1.25 tons/yd^3 for conversion of weights to volumes

Bed load transport has not been measured on San Francisquito Creek. Balance Hydrologics, Inc suggests that it may be from 10 to 20% of suspended load at the Stanford University gage, or about 1,000 to 2,000 yd^3. A better estimate can be obtained from the HEC-6 model output provided by **nhc** et al (2002). Their analysis shows an average sand component of 600 yd^3 and a gravel component of about 1,000 yd^3 per year near Los Trancos Creek. Bedload transport remains about this value until near El Camino, then declines rapidly by Highway 101. The sand component is thought to be included in the measured suspended load so only the gravel load is added for total load.

The above analyses suggests that long-term average sediment transport at the Stanford University gage is about 10,000 yd^3; divided roughly into 6,000 yd^3 of silt and clay wash load (60%) and 4,000 yd^3 of sand and gravel (40%).

7.3. Sediment Sources

OVERVIEW

Under current conditions, sediment is contributed to San Francisquito Creek from the following sources:

- Suspended sediment (silt and clay) carried over the Searsville Dam that originates in Corte Madera, Alambique and Sausal Creeks. This has been estimated to be 10% of the volume deposited in Searsville Lake.
- Los Trancos and Bear Creeks contribute fine and coarse sediment to the upper section of San Francisquito Creek. Previous chapters provide details on the sources of the sediment carried by these creeks.
- Erosion of stream banks along San Francisquito Creek.
- Incision of San Francisquito Creek into its streambed.

- Erosion from small tributaries, gullies and the land surface in the San Francisquito subwatershed.

Appendix D summarizes the sources of information on erosion and deposition in the San Francisquito subwatershed identified in the Historic Conditions Memorandum. Essentially, there is a reasonable understanding of coarse (sand and gravel) sediment erosion and deposition along the main creek from from 1964 to 1998. Bank erosion volumes along San Francisquito Creek are not well known, nor are erosion contributions from the surrounding urban areas.

nhc et al (2002) were not able to estimate bank erosion volumes by comparing repeated surveys, as many of the cross sections had been modified by construction of bank protection works. However, bank erosion along San Francisquito Creek is an important component of erosion and we estimated its contribution by balancing sediment inflows and deposition, assuming that the difference results from bank erosion. The following paragraphs describe the methods used to estimate erosion and deposition. Table 7.2 summarizes erosion and deposition volumes for 1964 to 1998.

SEARSVILLE LAKE, LOS TRANCOS AND BEAR CREEKS INFLOWS

Long-term sediment inflows from Searsville Lake are assumed to be 10% of the long-term reservoir deposition (Table 4-1) or about 1,700 yd^3 per year. All this sediment is assumed to be silt and clay.

Los Trancos and Bear Creeks are then assumed to contribute a net of 3,800 yd^3 per year of sand and gravel and 3,500 yd^3 per year of silt and clay, based on reducing the estimated sediment transport at the gage on San Francisquito Creek by the inflow from Searsville Lake and the inflows from sub-subwatersheds SF-10, SF-11 and SF-12. This contribution is larger than the long-term loads estimated from adjusting gaging records on Los Trancos and transferring them to Bear Creek (Sections 5.2 and 6.2). Note that part of the load from Bear Creek is deposited along San Francisquito Creek.

INCISION OF SAN FRANCISQUITO CREEK

nhc et al (2002), from comparison of the streambeds on the 1964 and 1998 surveys shows relatively slow incision from 1964 to 1998 upstream of Pope-Chaucer Bridge, amounting to 0.4 feet when spread over the bed, or a rate of about 0.012 feet/year. The calculated net incision was 4,800 yd^3, for an average of 140 yd^3 per year.

EROSION FROM SUB-SUBWATERSHEDS

Little is known of erosion sources or transport in the San Francisquito Creek sub-subwatersheds, particularly the urbanized ones in East Palo Alto, Palo Alto and Menlo Park. Instead of estimating erosion by adding sediment sources, we have relied on sediment transport measurements. Crippen and Waananen (1969) provide miscellaneous measurements of suspended sediment transport on Sharon Creek, Los Trancos tributary, and San Francisquito Creek tributary. These small tributaries all lie near the junction of San Francisquito and Los Trancos Creeks in the Bay Foothills. Sediment concentrations measured during storms ranged from a few hundred to more than 15,000 mg/L with associated sediment transport rates of less than 1 to about 400 tons per day. Storm hydrographs were very peaky and actual suspended transport during storms was often less than 10 tons (8 yd^3), reasonably consistent with storm-based erosion quoted by Knott *et al* (1973) for open space and urban areas in Colma Creek. Assuming that transported volumes range from about 1 to 50 tons for storms of varying size, average annual transport likely ranged from 100 to 300 yd^3/mi^2, depending on stream and watershed characteristics and the extent of construction.

Table 7-2: Annual Erosion and Annual Erosion by Grain Size to San Francisquito Creek from 1964 to 1998

Sediment Source	*Annual Erosion (yd^3)*	*Likely Range (%)*	*Comment*	*Annual Coarse Sediment (yd^3)* [1]	*Annual Fine Sediment (yd^3)* [1]
Erosion or Sediment Inflows					
Sediment from Searsville	1,700	±25%	Based on a few measurements	0	1,700
Los Trancos and Bear Creeks	7,300	±25%	From SF Creek gage	3,800	3,500
Incision	140	±25%	From surveys	140	0
Sub-subwatersheds SF-10 to SF-12	1,000	±75%	Very uncertain	200	800
Sub-subwatersheds SF-01 to SF-09	500	±75%	Very uncertain	200	300
Bank Erosion	*0 to 3,000*	±50%	Estimated from balance	*0 to 1,500*	*0 to 1,500*
Total Erosion	*10,600 to 13,600*			*4,300 to 5,800*	*6,300 to 7,800*
Deposition					
To Highway 101	470	±25%	From surveys	470	0
Highway 101 to mouth	1,000	±50%	Section uncertain	750	250
Excavation	900	±25%	Past excavation volume unknown	900	0
Delta	3,100	±25%	Depth of deposit uncertain	2,300	800
To San Francisco Bay	*5,200 to 6,600*	±50%	From fine sediment balance	0	*5,200 to 6,600*
Total Deposition	*10,600 to 13,600*		Based on error estimates	*2,000 to 5,700*	*6,300 to 7,800*

1. Coarse sediment is sand and larger (>0.063 mm); fine sediment is silt and clay (<0.063 mm).

Grain size analyses show that the suspended load was almost entirely silt and clay at moderate flows, increasing to about 40% sand at very high flows. On this basis, sand likely makes up 10 to 20% of the total load. Bed load transport does occur, as indicated by knickpoints along some of the streams.

Based on the transport analysis, we have assumed that annual contributions in sub-subwatersheds SF-10, SF-11 and SF-12, which are rural residential, are about 300 yd^3/mi^2. Contributions from the urbanized areas downstream are assumed to be much less, about 50 yd^3/mi^2. These yields are very much less than observed by Knott *et al* (1973) in Colma Creek but seem to be consistent with the general magnitude of sediment yields in San Francisquito Creek.

The above transport rates, with bank erosion contributions as discussed below are the basis of the erosion rates per unit area shown on Figures 6 and 7 for the San Francisquito Creek sub-subwatersheds.

BANK EROSION

The potential range of coarse sediment contribution from bank erosion, based on the difference between the range of deposited sediment and the range of eroded coarse sediment or contributions, is from 0 to 1,500 yd^3. The fine sediment component of bank erosion was estimated from the general nature of the bank materials along San Francisquito Creek. Banks are typically composed of sandy clay to clayey sand overlying sandy, silty gravels. We have assumed that the banks are about half coarse and half fine sediment, so the range of fine sediment eroded from banks is equal to that of coarse sediment. As discussed later, we have assumed that erosion is actually near the upper end of the quoted range.

DEPOSITION ALONG SAN FRANCISQUITO CREEK

Some of the bedload (gravel and sand) delivered by Bear Creek is deposited along San Francisquito Creek, with gravel deposited through Jasper Ridge downstream of the mouth of Bear Creek and sand deposited through sub-subwatershed SF-11. The net transport to the San Francisquito Creek gage is included in Table 7-2. Deposition in SF-11 has not been measured.

nhc *et al* (2002) calculated net deposition from Pope-Chaucer Bridge downstream to Highway 101 of 16,000 yd^3 by comparing 1964 and 1998 cross sections. This is roughly equivalent to 1.7 feet of deposition when spread over the streambed, or to about 0.06 yd^3/foot of channel per year. Average annual deposition is 470 yd^3 per year.

Deposition has also occurred from Highway 101 to the mouth of San Francisquito Creek, a distance of about 7,500 feet. The San Francisquito Creek CRMP (1998) reports that this reach was excavated to an invert elevation of between –3 and –4 feet and widened, with levees raised to increase capacity in 1958. The excavated channel has since filled to a typical invert elevation of –1 foot, with bars or berms of silty clay along the channel margins. The excavated section varies along the channel but we have roughly estimated a total deposition of 35,000 yd^3, roughly three-quarters sand and one-quarter fine sediment carried in from San Francisco Bay. Average annual deposition of sand is estimated to be 750 yd^3.

EXCAVATION FROM SAN FRANCISQUITO CREEK

Bed material has been historically removed from San Francisquito Creek to maintain the capacity of the Highway 101 Bridge and this is also part of the sediment balance. Table 7-3 summarizes the quantities that have been removed since 1984, as provided by the Santa Clara Valley Water District (SCVWD). Excavation volumes prior to 1984 are not reported and it is not known if material was not excavated or if was simply not recorded.

The total in Table 7-3 above includes excavation volumes in 2000 that lie outside the range of years in our sediment budget. Average annual excavation at the Highway 101 from 1984 to 1997 is 900 yd^3 per year and we have assumed that this rate is appropriate for the 1964 to 1998 period.

Table 7-3: Summary of Reported Excavation at Highway 101

Year	*Comment*	*Reported Volume (yd^3)*
1984	Upstream and downstream of 101	3,290
1993	Downstream of bridge	1,260
1998	Emergency work	3,080
1997	Downstream of bridge	4,630
2000	Downstream of bridge	4,882
Total		17,142

DEPOSITION ON SAN FRANCISQUITO DELTA

Phillips (2000) reported measurements of the deposition on the delta at the mouth of San Francisquito Creek in San Francisco Bay based on detailed coring. His results show five distinct fining-upward layers that are spread extensively over the delta, which he associated with the five largest floods since 1930 when the mouth of the creek was moved north. The individual layers are not dated and cannot be readily assigned to specific storms; however, the uppermost layer is certainly a result of the 1997-98 storms.

The volumes deposited during each event can be roughly estimated from the mapped area and the cores. It appears that the layer deposited on the delta during the 1997-98 El Nino storms averaged about 6 inches thick; based on the observed distribution of the flood deposits about 30,000 to 40,000 yd^3 appears to have been deposited. The volumes deposited during earlier floods are more difficult to interpret than from the 1997-98 storm. Significant deposition appears to have occurred during the 1982 storm. Total deposition since the late 1950s appear to be about one foot, or 80,000 yd^3. We assumed that this sediment is about three-quarters sand, providing an annual deposition rate of 2,300 yd^3. Some of the fine sediment may be carried to the delta by tidal currents rather than deposited from San Francisquito Creek.

7.4. Human Contributions to Erosion

The San Francisquito subwatershed is the most developed or urbanized watershed. We separate natural and human contributions to erosion, as follows:

- Estimated contributions from the land surface in the sub-subwatersheds are all assumed to be human-related (see Section 7.3 "Erosion from sub-subwatersheds")
- Incision of San Francisquito Creek is assumed to be all a result of human modification of hydrographs and from trapping of coarse sediment in Searsville Lake. This sediment contribution is divided equally between the SF-04, SF-05, SF-08 and SF-09 sub-subwatersheds
- Bank erosion along San Francisquito Creek is assumed to be half natural and half resulting from human modification. We assumed that the annual rate is at the top end of the range quoted in Table 7-2 and distributed this equally between sub-subwatersheds SF-02, SF-03, SF-04, SF-05, SF-08 and SF-09. This is, at best, a rough approximation. Bank erosion is thought to be negligible along San Francisquito Creek through SF-11, based on previous reports and field inspections (see Figures 6 and 7).

The above human-related contributions are crude estimates and further, detailed hydraulic analysis would be required to confirm these quantities.

7.5. San Francisquito Creek

San Francisquito Creek starts at the foot of Searsville Dam and flows to San Francisco Bay. The creek is incised into alluvial fan sediments along most of its course. We have divided the creek into four reaches, based primarily on slope and bed material, as follows:

- Reach 1 (Searsville Dam to Sandhill Road): bedrock-dominated reach
- Reach 2 (Sandhill Road to upstream of El Camino Real): boulder reach
- Reach 3 (Upstream of El Camino Real to University Avenue): gravel bed
- Reach 4 (Downstream of Newell Road): sand bed leading to estuary

Table 7-4 summarizes the basic characteristics of each reach.

Table 7-4: San Francisquito Creek Reach Characteristics

Reach	*Description*	*Slope*[1]	*Surface Material (mm)*[2]		*Subsurface Sediment*[3]
			D_{50}	D_{84}	
1	Bedrock reach	Not surveyed	30 to 120	100 to 200	Mostly fine gravel; 30% sand (lower end of reach)
2	Boulder reach	0.007	60	200	Assumed similar to Reach 1
3	Gravel bed reach	0.003	10 to 20	30 to 60	Mostly fine gravel; 30% sand
4	Sand bed reach	0.001	Sand	About 10	Mostly fine gravel; 20% sand

1. Slopes averaged from Figure 3-19 of RHAA et al (2000).
2. Bed material sizes from Figures 7-12 to 7-14 of **nhc** et al (2002)
3. Subsurface materials from Appendix B of **nhc** et al (2002). Sample weights are inadequate to fully characterize the subsurface bed material.

In Reach 1, San Francisquito Creek is incised into the local bedrock, which is exposed in the bed and in the lower section of the bank (Appendix A). Pleistocene fan deposits overlie the bedrock throughout much of the reach (see Helley et al 1979). **nhc** et al (2002) note that the contact with the fan deposits is typically about 5 feet above the stream bed in the upper reach, often higher near Los Trancos Creek, and that bedrock is no longer visible in the bank by Junipero Serra Boulevard (Pampeyan 1993). Bed material consists of gravel and cobbles near Bear Creek and cobbles and boulders downstream of this tributary; apparently, some gravel bars have also formed in the channel downstream of the mouth of Los Trancos Creek.

Reach 2 is a short boulder bed section of San Francisquito Creek that extends downstream past the bedrock-controlled section, onto the alluvial fan, to near the San Mateo Drive Pedestrian Bridge and the Pulgas Fault. The coarse bed material appears to be a stable pavement formed by winnowing of finer sediment from the bed surface; the underlying subsurface material appears considerably finer. The bed surface is now immobile or mostly immobile under the current flow regime. Closure of the Searsville Dam and reduction of coarse sediment supply, while maintaining peak flows, is likely a contributing factor to formation of the pavement.

Reach 3 is incising into coarse, partly indurated, gravels exposed below the sandy material that forms the upper banks and fan surface. Bed material is gravel, with sand in the interstices; subsurface materials are fine gravel and sand. The bed material in Reach 3 is reasonably mobile during annual peak flows and there is no evidence of formation of a stable pavement here. Bed incision is expected to continue at the upstream end of this reach, lowering the overall slope closer to a stable slope for the given bed material.

Reach 4 is a deposition reach that extends from University Avenue downstream to the estuary and delta of San Francisquito Creek. Bed materials in this reach consist of fine gravels and sand; subsurface materials have a similar grain size distribution.

7.6. Sediment Budget 1964 to 1998

Table 7-2 shows that erosion in San Francisquito Creek watershed averaged about 3,600 yd^3 per year, assuming that bank erosion along San Francisquito Creek occurred at the top end of the quoted range. If this is correct, bank erosion is the more important source, exceeding the estimated contribution from the urbanized landscape. However, there are broad uncertainties in the volume contributed by bank erosion, partly because of uncertainties in the other sediment inflow and deposition volumes and broad uncertainties in the volume eroded from urban areas and rural residential areas.

It is worth considering what the erosion volumes that are quoted in Table 7-2 imply for bank retreat along San Francisquito Creek. Such an analysis provides a rough check on the estimated volumes. Royston, Hanamoto, Alley, and Abbey *et al* (2000) examined the length of eroding bank along San Francisquito Creek in 1999. Table 7-5 summarizes the results for their four study reaches, showing that most of the unstable bank now lies from Pope-Chaucer Road upstream to Sand Hill Road, where San Francisquito Creek has been incising into its bed and increasing bank heights.

Table 7-5. Summary of Eroding Bank Length from RHAA (2000)

Reach	***Description***	***Reach Length (ft)***	***% Severe Erosion*** [1]	***Length of Severe Erosion*** [2] ***(ft)***
A	Hwy 101 to Pope-Chaucer	9,800	1%	200
B	Pope-Chaucer to Pedestrian Bridge	6,600	14%	1,800
C	Pedestrian Bridge to Sand Hill Road	12,800	60%	15,400
D	Sand Hill Road to USGS gage	3,200	0%	0
Totals		32,400	27%	17,400

1. Average of "least stable" category for left and right banks
2. Total bank length, right and left banks

Assuming that the banks are typically about 24 feet high, and have an average slope of 1.5H:1V, the total area of unstable bank would be about 80,000 yd^2. Further assuming that a similar bank area has been unstable since 1964, bank retreat at these sites would need to average about 1.3 yard (4 feet) normal to the slope (about 6 feet parallel to the streambed) since 1964 to account for the estimated erosion volume. Such a retreat is consistent with that observed between 1964 and 1998 at cross sections where stream banks are not protected from erosion, other than by vegetation, where bank retreat seems to average about 5 to 10 feet there (see **nhc** et al 2002). This suggests that bank erosion may be slightly underestimated or that sections of vegetated banks between these cross sections showed little or no erosion.

It is also of interest to examine the average channel widening associated with the bank erosion. For the channel from Highway 101 to the USGS gage, the average bank retreat from 1964 to 1998 to match the estimated erosion volume would be about 0.4 yards (1.1 foot) normal to the slope, or an average widening of about 1.5 feet at the base of the bank slope. Steepening of some banks and construction of protection on other banks may mask any effects of the apparent widening of the overall valley. There are no measurements of average channel or valley widths over time along San Francisquito Creek but RHAA et al (2000) note that bank stability was already an issue in the 1960s and channel widening is likely to have occurred along the creek.

7.7. Budget Without Searsville Dam

The sediment budget quoted in Table 7-2 is for existing conditions in the San Francisquito Watershed, with Searsville Dam in place. The dam traps sediment from the Searsville Lake Watershed and has reduced the supply of coarse and fine sediment to San Francisquito Creek since 1892, when the dam was closed. Table 7-6 summarizes long-term average coarse and fine sediment loads in San Francisquito Creek, for both existing conditions and for no dam. Sediment loads without Searsville Dam assume that the long-term average load from the Searsville Watershed quoted in Table 4-1 would be carried to San Francisquito Creek and that it is half coarse and half fine sediment.

Table 7-6. Average Annual Sediment Budgets at the San Francisquito gage at Stanford with and without Searsville Dam[1]

Sediment Source	***Scenario 1 – Existing Conditions***	***Scenario 2 – No Searsville Dam***	***Scenario 1 – Existing Conditions***	***Scenario 2 – No Searsville Dam***
	Annual Coarse Load (yd^3)[2]		*Annual Fine Load (yd^3)*[2]	
Searsville Watershed[2]	0	8,500	1,700	8,500
Los Trancos and Bear Cks	3,800	3,800	3,500	3,500
Sub-subwatersheds SF-10 to 12	200	200	800	800
Bank Erosion along San Francisquito Ck	minor	Increased?	minor	Increased?
Transport and Deposition	4,000	12,500	6,000	12,800

1. Average for San Francisquito Creek is from 1964 to 1998; for Searsville watershed from 1982 to 2000
2. Coarse sediment is sand, gravel and cobbles; fine sediment is silt and clay.

Table 7-6 shows that coarse sediment loads in San Francisquito Creek have been reduced by about two-thirds and fine sediment loads by one-half as a result of the Searsville Dam and reservoir. Note that the loads calculated with and without the dam do not represent "natural" loads as they include a human-related erosion component.

Reduction of the coarse load to San Francisquito Creek is thought to be responsible for some of the historic changes observed along the creek. Incision in upper reaches and deposition in lower reaches has likely occurred as part of an overall adjustment to lower bed load transport. This incision has increased bank heights, steepening some bank and increasing rates of erosion. One other response to the reduced coarse sediment supply has been coarsening of the bed material and formation of a coarse pavement in the upper reaches of the creek.

On the other hand, trapping of fine sediment has likely resulted in improved water quality (lower average sediment concentration and turbidity) with few consequences for the stream channel. This fine sediment is mostly carried through San Francisquito Creek to San Francisco Bay.

8. SUMMARY AND CONCLUSIONS

Sediment budgets were prepared for 1995 to 2000 for Searsville Lake, Los Trancos and Bear subwatersheds. Based on surveys of deposition in Searsville Lake and sediment transport measured at other stations, unusually high erosion and sediment transport appeared to occur in the all three subwatersheds over this period. Longer-term budgets, that reflect average conditions, were also prepared for these three subwatersheds and for the San Francisquito subwatershed.

The budget constructed for Searsville Lake from 1995 to 2000 is thought to be the most accurate, because it is based largely on rates of erosion measured in the watershed and it is verified or closed by measured deposition in Searsville Lake. The Los Trancos budget is less accurate because of fewer measurements of rates of erosion in the watershed. The Bear budget is least accurate as transport measurements are not certain and few rates of erosion have been measured in the watershed. The long-term budgets for the three subwatersheds are less accurate again as they rely on adjusting the short-term budgets to match long-term sediment transport.

A detailed sediment budget for the Searsville Watershed for 1995 to 2000 shows that about half of the sediment was eroded from two sub-subwatersheds in upper Corte Madera Creek and that nearly all of the sediment came from Corte Madera; other tributaries to Searsville Lake contributed much less to the total deposition in Searsville Lake. Landslides that originated on lower valley walls and along the stream channel were the greatest contributors to the total erosion; landslides originating on upper and mid-valley slopes were the second most important contributors. Both stream bank erosion and surface erosion were relatively insignificant to the total erosion during this period. Undercutting and removal of toe support by channel shifting and incision are thought to be important causes of the landslides along the lower valley walls and it appears that the extreme flood in 1998 was an important trigger of the very high erosion and transport rates from this source. Human impacts accounted for about 16% of total erosion, primarily from human-related landslides and surface erosion along roads.

Long-term average annual sediment deposition in Searsville Lake is less than 40% of that from 1995 to 2000; deposition during some periods is only 15% of that from 1995 to 2000. The relative importance of different components of the sediment budget changes for long-term conditions and for periods of relatively low erosion. Landsliding on mid- and upper slopes seems to occur frequently, is not as driven by channel incision, and appears to be the important contributor to the long-term sediment production. These mid-slope landslides may be initiated by human activities, such as road construction or drainage diversion from roads or other structures. Chronic sediment sources, such as surface erosion and bank erosion, are significant components of the sediment budget during dry years. The main human contributions to surface erosion are direct impacts, through erosion along paved and unpaved roads and drainage modification of gullies. Hydromodification is significant in some sub-subwatersheds but not very significant in the main stream, except for modifications of stream banks Portola Valley and by encroachment of Alpine Road. Human impacts on long-term erosion are not as well known as for 1995 to 2000 but may amount to 20 to 50%, depending on the role of development on landsliding. They likely lie near the lower end of this range.

The sediment budgets for Los Trancos and Bear subwatersheds for 1995 to 2000 and for the long-term are much less certain than for Corte Madera Creek because less detailed erosion and transport measurements are available in these watersheds. Both short-term and long-term erosion rates in Los Trancos and Bear Creek watersheds are very much lower than in Searsville Lake watershed. Long-term erosion from Los Trancos and Bear Creek watersheds is only about one-quarter of that from Searsville Lake watershed, despite the much larger area in the Bear and Los Trancos subwatersheds. The greater erosion seems to result from a combination of erosive geologies (particularly the Santa Cruz formation), steep stream slopes, and plentiful historic deep-seated landslides, which accelerate colluvial contributions to lower valley walls.

Sediment from the Searsville Lake Watershed is mostly deposited behind Searsville Dam, and only silt and clay are carried over the dam to San Francisquito Creek. Consequently, under existing conditions, the erosion that contributes to the San Francisquito Creek sediment budget is from the Los Trancos, Bear and San Francisquito Creek watersheds. Table 8-1 summarizes the dominant erosion processes in the three subwatersheds.

Table 8-1: Summary of Long-Term Dominant Erosion Processes

Subwatershed	*Dominant Erosion Processes*	*Human Impacts on Erosion Processes*
Los Trancos	Landslides from slopes	Acceleration of landslides rates by development; road erosion
Bear	Bank erosion and streambank landslides in upper sub-subwatersheds; landslides from slopes	Impacts on stream bank stability; incision on Bear Gulch from trapping of coarse sediment; road erosion
San Francisquito	Bank erosion along San Francisquito; erosion from subdivisions	Increased peak flows; trapping of coarse sediment in Searsville Lake

Development that alters stream hydrographs does not seem to be important in either Los Trancos or Bear subwatersheds. However, human modifications of stream banks may contribute to erosion, particularly along the SAFZ in Woodside.

Los Trancos Creek seems to show little channel incision or bank erosion along the main channel and landslides in the upper watershed dominate the sediment budget. The impacts of development on landsliding seem to be main human impact on erosion.

The sediment budget is Bear Creek is less certain than that of Los Trancos Creek. For 1995 to 2000, estimated sediment transport exceeded erosion and a streamside landslide component was added to balance the budget. This erosion from this component is only roughly estimate and may be very inaccurate because of inaccuracies in total transport and erosion from other sources. Field inspection indicates very active streamside erosion in some upper sub-subwatersheds, such as McGarvey Creek, but the total quantity estimated may be considerably in error.

Bank erosion and streamside landslides are the dominant processes from 1995 to 2000. Over the long-term landslides from slopes also become a dominant erosion process. Few such landslides were observed between 1995 and 2000, possibly as a result of areal variations in rainfall intensity, but the longer-term inventory shows reasonably frequently shallow landslides in the watershed.

Human impacts on erosion in Bear Creek were relatively minor from 1995 to 2000, primarily resulting from modifications of stream banks and potential impacts on gullies. Long-term impacts are expected to occur on these same processes and to be a relatively small portion of total erosion.

In San Francisquito subwatershed, erosion from human impacts dominates natural sources. The main processes seem to be erosion and incision along San Francisquito Creek from trapping of sediment behind Searsville Dam and modification of the flood hydrograph along Searsville Creek by development. Land and stream erosion from development in the upper part of the subwatershed may also be important. Unfortunately, neither rates of bank erosion along San Francisquito Creek or rates of erosion in small tributaries are accurately known.

Prior to construction of Searsville Dam, the long-term average coarse sediment transport through San Francisquito Creek was likely three times greater than it is now, based on comparing measured sand and gravel transport at the Stanford gage to long-term transport to Searsville Lake. It is our view that this reduction of coarse sediment transport has contributed to the historic changes observed along San Francisquito Creek. Slope adjustments in response to the lowered sediment transport are thought to be an important cause of the incision on the upper part of the alluvial apron and the deposition along the lower course of San Francisquito Creek. Other likely stream impacts include coarsening of the streambed in the upper creek, leading to formation of a coarse armor layer.

9. REFERENCES

Allardt, G. and C. Grunsky. 1888. Investigations of San Francisquito Creek. Submitted to Manzanita Water Company. Stanford, California. 20 p.

Anderson, R. 1908. Earth-flows at the time of the San Francisco Earthquake (Abstract). Bulletin of the Geological Society of America 18: 643.

Anderson, R.S. 1994. Evolution of the Santa Cruz Mountains, California. Journal of Geophysical Research 99(B10): 20.168 to 20.179.

Brabb, E. and E. Pampeyan. 1972. Preliminary map of landslides in San Mateo County, California. USGS Miscellaneous Field Studies Map MF-344. Scale 1:62,500.

Brabb, E., E. Pampeyan and M. Bonilla. 1972. Landslide susceptibility in San Mateo County, California. USGS Miscellaneous Field Studies Map MF-360. Scale 1:62,500.

Brabb, E., R. Graymer and D. Jones. 2000. Geologic map and map databases of the Palo Alto 30' X 60' Quadrangle, California. USGS Miscellaneous Field Studies Map MF-2332 and Pamphlet. 30 pp.

Brown, A.K. 1966. Sawmills in the Spanish Red Woods. San Mateo County Historical Association.

Brown, W. 1973. Erosion processes, fluvial sediment transport and reservoir sedimentation in a part of the Newell and Zayante Creek Bains, Santa Cruz County, California. USGS Open-File Report. Water Resources Division, Menlo Park, CA.

Brown, W. 1988. Historic setting of the storm: Perspectives on population, development, and damaging rainstorms in the San Francisco Bay region *in* Ellen, S. and G. Weiczorek (ed). Landslides, floods, and marine effects of the storm of January 3-5, 1982 in the San Francisco Bay Region, California. USGS Professional Paper 1434: 7-16.

Brown, W. and J. Jackson. 1973. Erosional and deposition provinces and sediment transport in the south and central part of the San Francisco Bay Region, California. USGS Miscellaneous Field Studies MF-515. 21 p. Pamphlet and Maps.

Buchan, L and M. Hayden. 2000. Inventory of Santa Clara Basin Stream Studies. Santa Clara Valley Urban Runoff Pollution Prevention Program.

Burgmann, R., R. Arrowsmith, T. Dumitru and R. McLaughlin. 1994. Rise and fall of the southern Santa Cruz Mountains, California from fission tracks, geomorphology and geodesy. Journal of Geophysical Research 99(B10): 20.181 to 20.202.

California Department of Fish and Game. 1974. San Francisquito Creek drainage streamflow measurements and fish sampling. Bear, Corte Madera and Los Trancos (July 31). Menlo Park.

California Department of Fish and Game. 1976. San Francisquito Creek drainage streamflow measurements and fish sampling. Walk of Bear Creek to San Francisquito Creek (June 24). Menlo Park.

California Department of Fish and Game. 1981. San Francisquito Creek drainage streamflow measurements and fish sampling. Walk of Upper San Francisquito Creek (June 30). Menlo Park.

Cannon, S. and S. Ellen. 1983. Rainfall that triggered abundant debris avalanches in the San Francisco Bay region, California, during the storm of January 3-5, 1982. USGS Open-File Report 83-10.

Cannon, S. and S. Ellen. 1985. Abundant debris avalanches, San Francisco Bay Region, California. California Geology 38(12): 267-72.

Chebanov, A. undated. Application of microgenesis level methods for San Francisquito Creek runoff model, San Francisquito Creek watershed, California, USA. Unpublished report to the United States Geological Survey.

Corps of Engineers. 1972. Survey Report on San Francisquito Creek, San Mateo and Santa Clara Counties, California, for Flood Control and Allied Purposes. U.S. Army Engineer District, San Francisco, California. 27 pp.

Coyote Creek Riparian Station. 1994. San Francisquito Creek creek survey summary 1993-94. San Francisquito Creek Coordinated Resource Management and Planning.

Coyote Creek Riparian Station. 1998. San Francisquito Creek upper watershed volunteer monitoring program (November 97 to October 98). San Francisquito Creek Coordinated Resource Management and Planning.

Creasey, C.L. 1988. Landslide damage: A costly outcome of the storm *in* Ellen, S. and G. Weiczorek (ed). Landslides, floods, and marine effects of the storm of January 3-5, 1982 in the San Francisco Bay Region, California. USGS Professional Paper 1434: 195-204.

Crippen, J.R. and A. Waananen. 1969. Hydrologic Effects of Suburban Development near Palo Alto, California. USGS Open-File Report. January 23. 35 pp.

Cummings, J. and Wm. Spangle & Associates (Compilers). 1975. Geologic Map: Town of Portola Valley, San Mateo County, California. Scale 1:6,000

Cushing, K.K. 1999. After the flood waters receded: Assessing the economic effects of San Francisquito Creek February 1998 flooding. US Army Corps of Engineers and Santa Clara Valley Water District.

Dickinson, W., J. Cummings and Wm. Cotton and Associates. 1992(?). Geologic Map: Town of Woodside, San Mateo County, California. Scale 1:7,200.

Ellen, S., M. Algus, S. Cannon, R. Fleming, P. Lahr, D. Peterson and S. Reneau. 1988. Description and mechanics of soil slip/debris flows in the storm. *in* Ellen, S. and G. Weiczorek (ed). Landslides, floods, and marine effects of the storm of January 3-5, 1982 in the San Francisco Bay Region, California. USGS Professional Paper 1434: 63-112.

Ellen, S., R. Mark, G. Wieczorek, C. Wentworth, D. Ramsey and T. May. 1997. Map showing principal debris-flow source areas in San Mateo County, California. USGS Open-File Report 97-745E. Sheet 7 of 11. Scale 1:125,000.

Ellen, S. and G. Weiczorek 1988. (eds). Landslides, floods, and marine effects of the storm of January 3-5, 1982 in the San Francisco Bay Region, California. USGS Professional Paper 1434. 310 pp and Plates.

Fio, J and D. Leighton. 1995. Geohydrologic framework, historical development of the ground-water system, and general hydrologic and water-quality conditions in 1990, south San Francisco Bay and peninsula area, California. USGS Open-File Report 94-357. 46 p.

Frey, C. 2001. Geomorphic Study of Searsville Lake Watershed, Portola Valley, California. M.Sc Thesis, San Jose State University. 137 pp.

Godt, J. (ed). 1999. Maps showing locations of damaging landslides caused by El Nino rainstorms, winter season 1997-98, San Francisco Bay region, California. USGS Miscellaneous Field Investigation MF-2325A-J. 11 p.

Helley, E, K. Lajoie, W. Spangle and M. Blair. 1979. Flatland deposits of the San Francisco Bay Region, California – their geology and engineering properties and their importance to comprehensive planning. USGS Professional Paper 943. 88 pp.

Inman, D. and S. Jenkins. 1999. Climate change and the episodicity of sediment flux of small California Rivers. Journal of Geology 107: 251-270.

Iwamura, T.I. 1980. Saltwater intrusion investigation in the Santa Clara County baylands area, California. Santa Clara Valley Water District. 115 p.

Jayko, A, J. De Mouthe, K. Lajoie, D. Ramsey and J. Godt. 1999. Map showing locations of damaging landslides in San Mateo County, California, resulting from 1997-98 El Nino Rainstorms. USGS Miscellaneous Field Studies Map MF-2325-H.

Jayko, A., M. Rymer, C. Prentice, R. Wilson and R. Wells. 1998. The Scenic Drive Landslide Jan-Feb 1998, La Honda, San Mateo County, California. USGS Open-File Report 98-229. One Plate.

Keefer, D., R. Wilson, R. Mark, E. Brabb, W. Brown, S. Ellen, E. Hard, G. Weiczorek, C. Alger and R. Zatkin. 1987. Real-time landslide warning during heavy rainfall. Science 238: 921-925.

Keefer, D. (ed). 1998. The Loma Prieta, California, Earthquake of October 17, 1989 – Landslides. USGS Professional Paper 1551-C.

Keefer, D, G. Griggs, and E. Harp. 1998. Large landslides near the San Adreas fault in the Summit Ridge area, Santa Cruz Mountains, California in Keefer, D. (ed) The Loma Prieta, California, Earthquake of October 17, 1989 – Landslides. USGS Professional Paper 1551-C: p. C71-C128.

Kittleson, G., B. Hecht and D. Holmes. 1996. Sedimentation and channel dynamics of the Searsville Lake Watershed and Jasper Ride Biological Preserve, San Mateo County, California. Balance Hydrologics, Inc. June 30.

Knott, J.M. 1973. Effects of Urbanization on Streamflow and Sediment Discharge in the Colma Creek Basin, California. USGS Open-File Report. 54 pp.

Lawson, A.C (chairman). 1908. The California Earthquake of April 18, 1906: Report of the State Earthquake Investigation Commission. Carnegie Institute of Washington, Publication 87. 2 Volumes.

Lehre, A. 1982. Sediment budget of a small coast range drainage basin in North-Central California *in* Swanson, F.J., R. Janda, T. Dunne and D. Swanston (eds). Sediment Budgets and Routing in Forested Drainage Basins. USDA Forest Service. Pacific Northwest Forest and Range Experiment Station. General Technical Report PNW-41. p. 67-77.

Manson, M, D. Keefer, and M. McKittrick. 1992. Landslides and other geologic features in the Santa Cruz Mountains, California, resulting from the Loma Prieta Earthquake of October 17, 1989. California Division of Mines and Geology Open-File Report 91-05. 45 p and 15 plates. Scale 1:48,000.

Mark, R.K. 1992. Maps of debris-flow probability, San Mateo County, California. USGS Miscellaneous Investigations Series Map 1-1257-M. Scale 1:62,500.

McCashion, J. and R. Rice. 1983. Erosion on logging roads in northwestern California: how much is avoidable? Journal of Forestry. vol 81(1). 23-26.

Metzger, L. 2002. Streamflow Gains and Losses along San Francisquito Creek and, Characterization of Surface-Water and Ground-Water Quality, Southern San Mateo and

Northern Santa Clara Counties, California, 1996-97. USGS Water-Resources Investigations Report 02-4078. 28 pp.

Metzger, L. and J. Fio. 1997. Ground-water development and the effects on ground-water levels and water quality in the town of Atherton, San Mateo County, California. USGS Water-Resources Investigation 97-4033. 31 p.

Napier, G, J. Perkins, R. Moreland, R. Mark and E. Brabb. 1992. Maps showing land use and land cover in Sam Mateo County, California. USGS Miscellaneous Investigations Map I-1257-L. Scale 1:62,500.

Nilsen, T, F. Taylor and R. Dean. 1976. Natural conditions that control landsliding in the San Francisco Bay region – an analysis based on data from the 1968-69 and 1972-73 rain seasons. USGS Bulletin 1424.

Nolan, K and D. Marron. 1985. Contrasts in stream-channel response to major storms in two mountainous areas of California. Geology 13(2): 135-138.

Nolan, K and D. Marron. 1988. Stream-channel response to the storm in Santa Cruz Mountains *in* Ellen, S. and G. Weiczorek (ed). Landslides, floods, and marine effects of the storm of January 3-5, 1982 in the San Francisco Bay Region, California. USGS Professional Paper 1434: 245-264.

Northwest Hydraulic Consultants and Jones & Stokes Associates. 1999. Family Farm Road Flood and Sediment Control Study. Phase 2 – Schematic Design Plan. Stanford University, Facilities Operation.

Northwest Hydraulic Consultants and Jones & Stokes Associates. 2003. San Francisquito Creek Watershed, Historic Conditions Analysis, Draft Report. San Francisquito Creek Joint Powers Authority. 29 p and Appendices.

Northwest Hydraulic Consultants, Balance Hydrologics, Inc, H.T. Harvey & Associates, Jones & Stokes, Dr. Matt Kondolf and Dr. Jerry Smith. 2002. Searsville Lake Sediment Impact Study. Stanford University, Facilities Operation. 186 p and Appendices.

Owens, J., S. Chartrand and B. Hecht. 2002. Annual hydrologic record and sediment yield, Corte Madera Creek, Portola Valley, California: Data report for Water Year 2001. Balance Hydrologics, Inc for Stanford University, Facilities Operations Dept.

Owens, J., S. Chartrand and B. Hecht. 2002. Annual hydrologic record and sediment yield, Los Trancos Creek, Portola Valley, California: Data report for Water Year 2001. Balance Hydrologics, Inc for Stanford University, Facilities Operations Dept.

Pike, R., R. Graymer, S. Roberts, N. Kalman and S. Sobieszczyk. 2001. Map and map database of susceptibility to slope failure by sliding and earthflow in the Oakland area, California. USGS Miscellaneous Field Studies MF-2385. 37 p and Maps.

Phillips, R.L. 2000. Sedimentation of the flood tidal delta of San Francisquito Creek, South San Francisco Bay, California. US Geological Survey Presentation.

Poland, J. and R. Ireland. 1988. Land subsidence in the Santa Clara Valley, California, as of 1982. USGS Professional Paper 497-F. 61 p.

Porterfield, G. 1980. Sediment Transport of Streams Tributary to San Francisco, San Pablo, and Suisun Bays, California, 1909-66. US Geological Survey Water-Resources Investigation 80-64. 87 p.

Reid, L. and T. Dunne. 1984. Sediment production from forest road surfaces. Water Resources Research. vol 20(11). 1753-1761.

Reid, L. and T. Dunne. 1996. Rapid Evaluation of Sediment Budgets. Catena Verlag GMBH Geoecology Paperback. Germany. 164 pp.

Rice, R. 1999. Erosion on logging roads in Redwood Creek, northwestern California. Journal of the American Water Resources Association. vol 35(5). 1171-1182.

Rodine, J.D, C. Price and others. 1975. Geology and movement potential within the Town of Portola Valley, California. Town of Portola Valley.

Royston, Hanamoto, Alley and Abey, Philip Williams & Associates, H.T. Harvey & Associates, Environmental Science Associates and Frederick T. Seher & Associates. 2000. San Francisquito Creek Bank Stabilization and Revegetation: Existing Conditions Report. Prepared for City of Menlo Park, City of Palo Alto, City of East Palo Alto, Santa Clara Valley Water District and County of San Mateo. 121 pp.

San Francisquito Creek Coordinated Resource Management and Planning (CRMP). 1998. Reconnaissance Investigation Report of San Francisquito Creek. Flood and Erosion Control Task Force, Palo Alto. 85 p.

Santa Clara Basin Watershed Management Initiative (SCBWMI). 2000 (May). Watershed management plan. Volume One: Watershed characteristic report. 165 pp.

Smith, J.J. and D. Harden. 2001. Adult Steelhead passage in the Bear Creek Watershed. San Francisquito Watershed Council. 65 p.

Smith, T. and E. Hart. 1982. Landslides and related storm damage: January 1982, San Francisco Bay Region. California Geology 35(July): 139-152.

Smith, T. 1988. A method for mapping relative susceptibility to debris flows, with an example from San Mateo County *in* Ellen, S. and G. Weiczorek (ed). Landslides, floods, and marine effects of the storm of January 3-5, 1982 in the San Francisco Bay Region, California. USGS Professional Paper 1434: 195-204.

Sokol, D. 1964. The hydrogeology of the San Francisquito Basin, San Mateo and Santa Clara Counties, California. Unpublished Ph.D Dissertation. Stanford University, Palo Alto. 238 p.

Stanger, F.M. 1967. Sawmills in the Redwoods: Logging on the San Francisco Peninsula, 1849-1967. San Mateo County Historical Association.

Swanston, D.N. and F.J. Swanston. 1976. Timber harvesting, mass erosion, and steepland forest geomorphology in the Pacific Northwest in Coates, D.R. (ed). Geomorphology and Engineering. Dowden, Hutchinson and Ross. Stroudsburg, PA. p. 199-221.

Taylor, F. and E. Brabb. 1972. Maps showing distribution and cost by counties of structurally damaging landslides in the San Francisco Bay region, California, winter of 1968-69. USGS Miscellaneous Field Studies Map MF-327. Scales 1:500,000 and 1:1,000,000.

Taylor, F., T. Nilsen and R. Dean. 1975. Distribution and costs of landslides that have damaged manmade structures during the rainy season of 1972-73 in the San Francisco Bay region, California. USGS Miscellaneous Field Studies Map MF-679. Scales 1:500,000 and 1:1,000,000.

United States Geologic Survey. 2003. Western Geoscience Center GIS Database for San Francisquito Creek (http://wgsc.wr.usgs.gov/sfcreek/).

Varnes, D.J. 1978. Slope movement types and processes *in* Schuster, R.L. and R.S. Krizek (eds). Landslides: Analysis and Control. US National Academy of Sciences. Transportation Research Board Special Report 176. p. 11-33.

Wentworth, C.M. 1986. Maps of debris flows evident after the storms of December 1955 and January 1982, Montara Mountain Area, California. USGS Open-File Map 86-363. Scale 1:24,000

Wentworth, C., S. Ellen, V. Frizzell, Jr. and J. Schlocker. 1985. Map of Hillside Materials and Description of Their Engineering Character, San Mateo County, California. USGS Miscellaneous Investigations Series Map I-1257-D. Two Sheets.

Wentworth, C., S. Graham, R.J. Pike, G. Buekelman, D. Ramsey and A. Barron. 1997. Summary of distribution of slides and earth flows in San Mateo County, California. USGS Open-File Report 97-745C. 10 p and 11 sheets.

Wieczorek, G.F. 1982. Map showing recently-active and dormant landslides near La Honda, central Santa Cruz Mountains, California. USGS Miscellaneous Field Studies Map MF-1422. Scale 1:4,800.

Weiczorek, G.F., E. Harp and R. Mark. 1982. Debris flows and other landslides in San Mateo, Santa Cruz, Contra Costa, Alameda, Napa, Solano, Lake and Yolo Counties, and factors influencing debris flow distribution *in* Ellen, S. and G. Weiczorek (eds). Landslides, floods, and marine effects of the storm of January 3-5, 1982 in the San Francisco Bay Region, California. USGS Professional Paper 1434: 133-161.

Wieczorek, G.F and J. Sarmiento. 1983. Significance of storm intensity-duration for triggering of debris flows near La Honda, California. Geological Society of America Abstracts with Programs 15(5): 289.

Wilson, R.C. and A. Jayko. 1997. Preliminary maps showing rainfall thresholds for debris-flow activity, San Francisco Bay region, California. USGS Open-File Report 97-745 F, 20 pp (scale 1:275,000).

Youd, T. and S. Hoose. 1978. Historic ground failures in northern California triggered by earthquakes. USGS Professional Paper 993. 177 p.

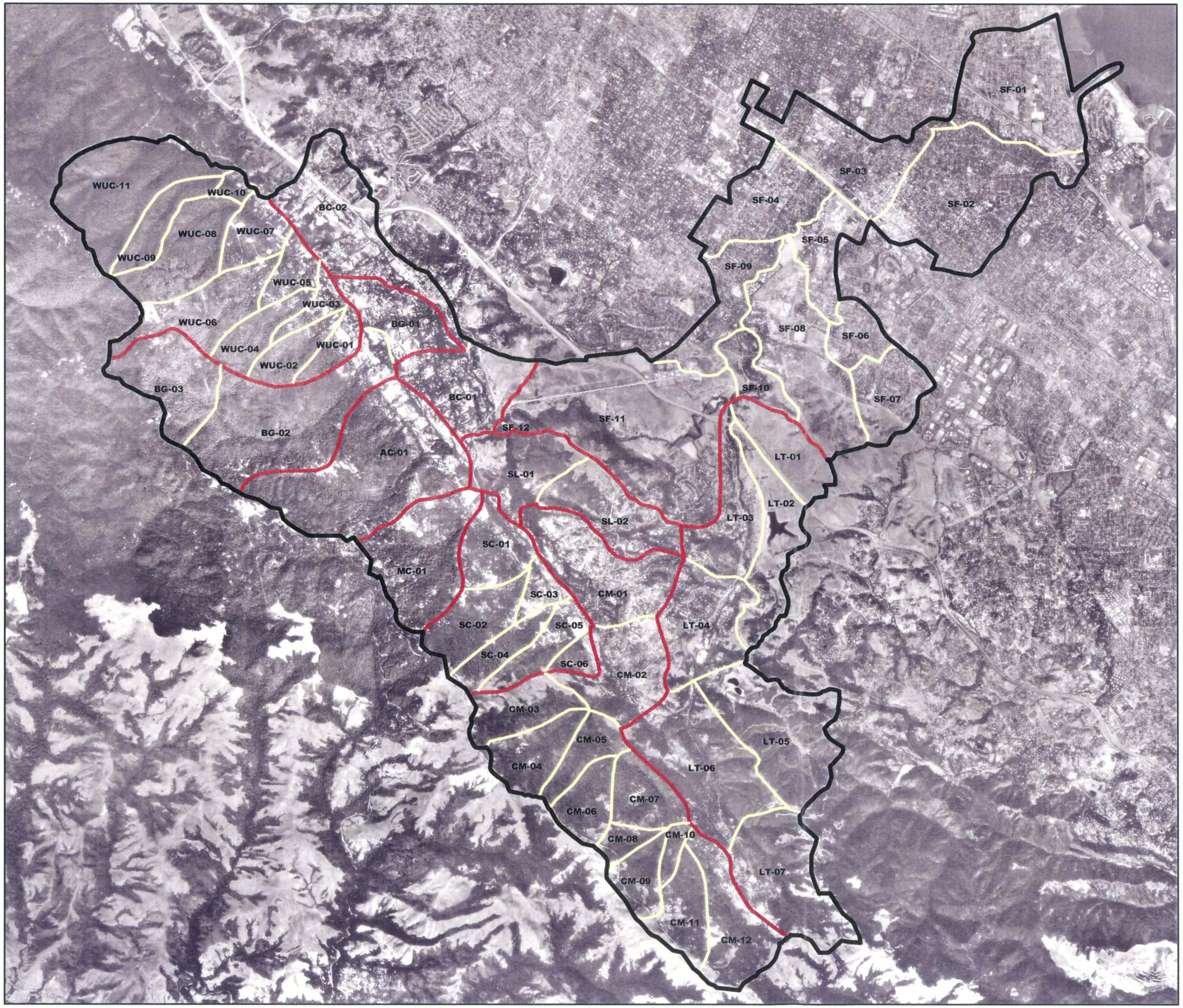


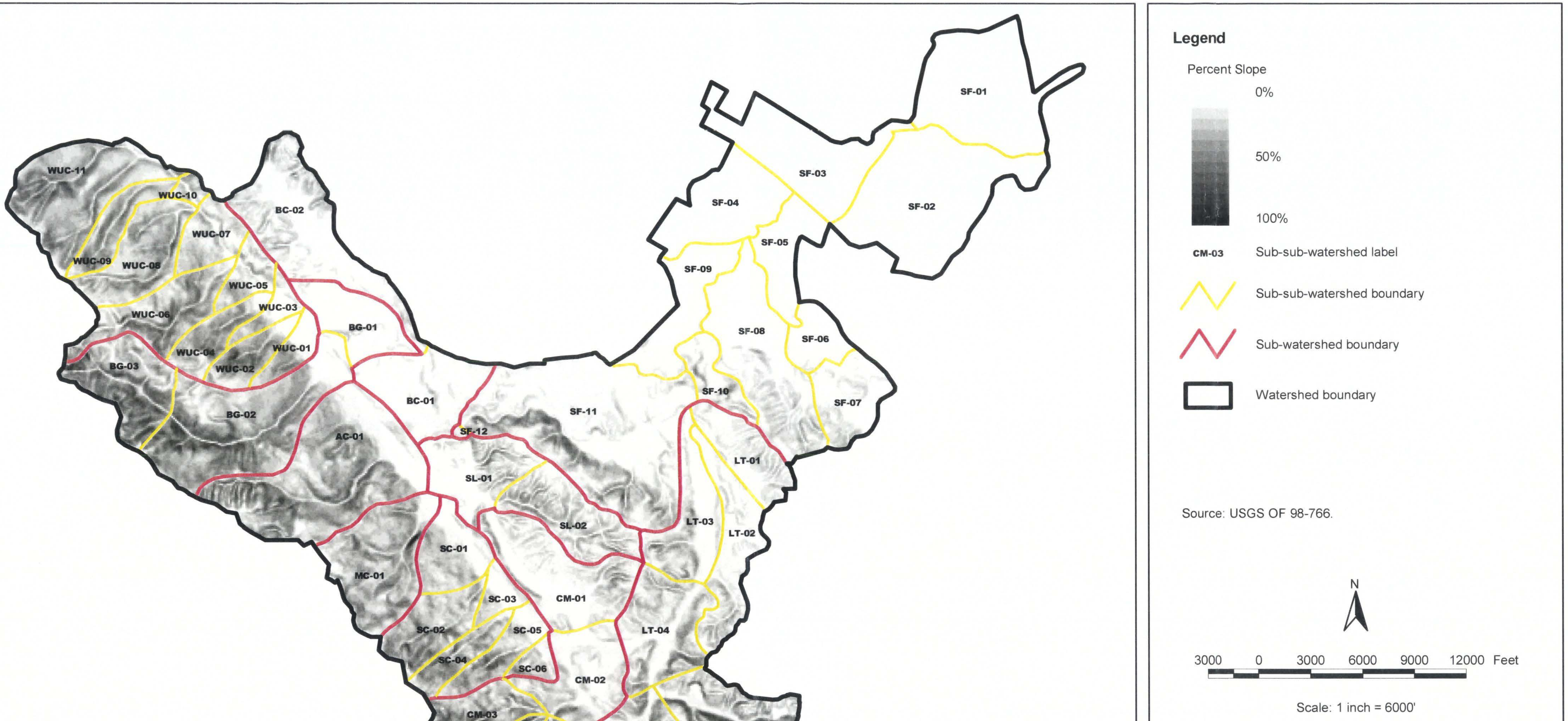
Figure 1
Watershed and Sub-Watershed Boundaries
San Francisquito Creek Basin

San Francisquito Creek Watershed Analysis and Sediment Reduction Plan

San Francisquito Creek Joint Powers Authority

nhc
northwest hydraulic consultants, inc.
3950 industrial boulevard, suite 100c
west sacramento, california 95691
(916) 371-7400

Jones & Stokes



Source: USGS OF 98-766.

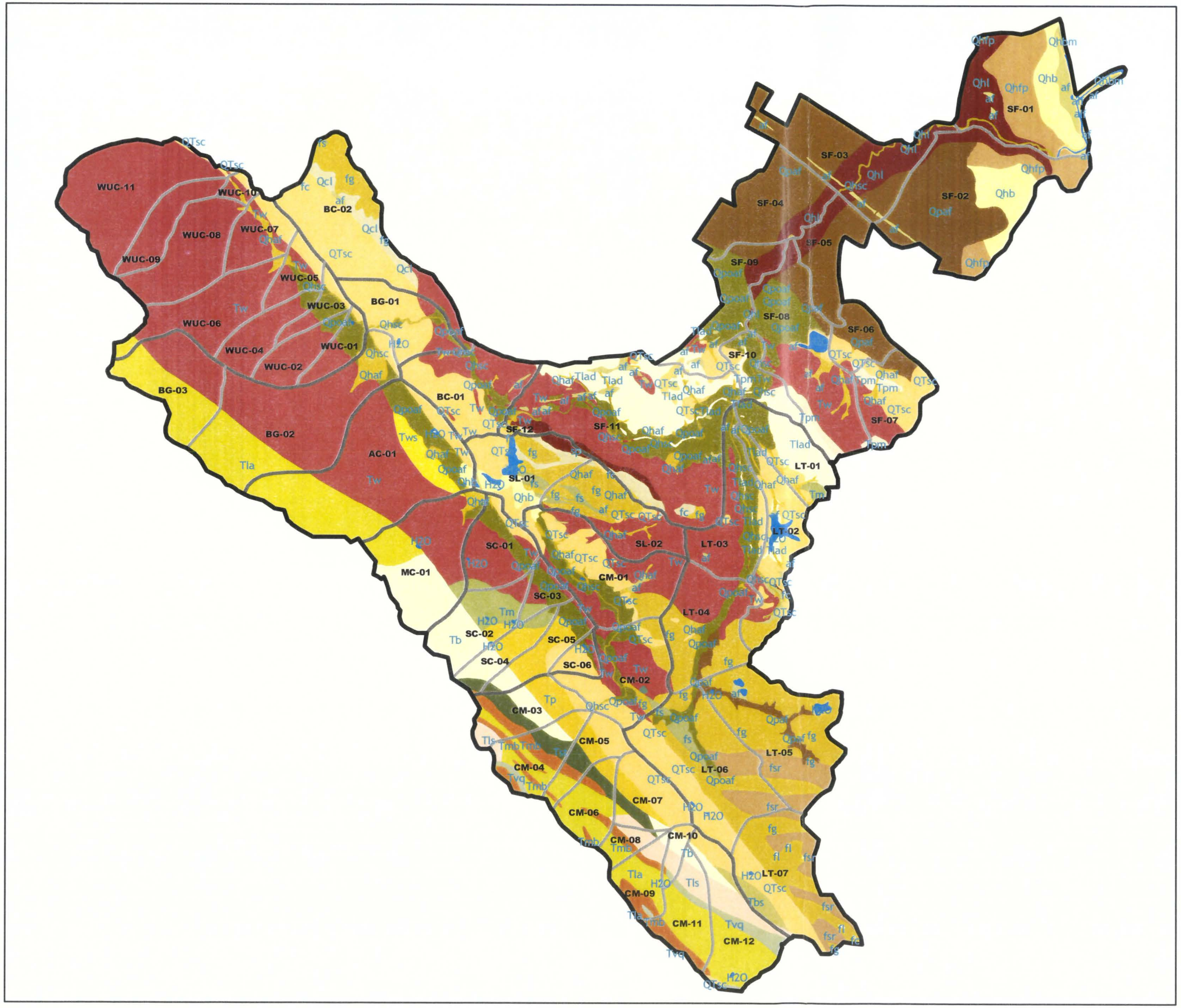
Figure 2
Slope
San Francisquito Creek Basin

San Francisquito Creek Watershed Analysis and Sediment Reduction Plan

San Francisquito Creek Joint Powers Authority

nhc northwest hydraulic consultants, inc.
3950 industrial boulevard, suite 100c
west sacramento, california 95691
(916) 371-7400

Jones & Stokes



Source: USGS Palo Alto, CA geologic map database (2000).

Figure 3
Geology
San Francisquito Creek Basin

San Francisquito Creek Watershed Analysis and Sediment Reduction Plan

San Francisquito Creek Joint Powers Authority

nhc northwest hydraulic consultants, inc.
3950 industrial boulevard, suite 100c
west sacramento, california 95691
(916) 371-7400

Jones & Stokes

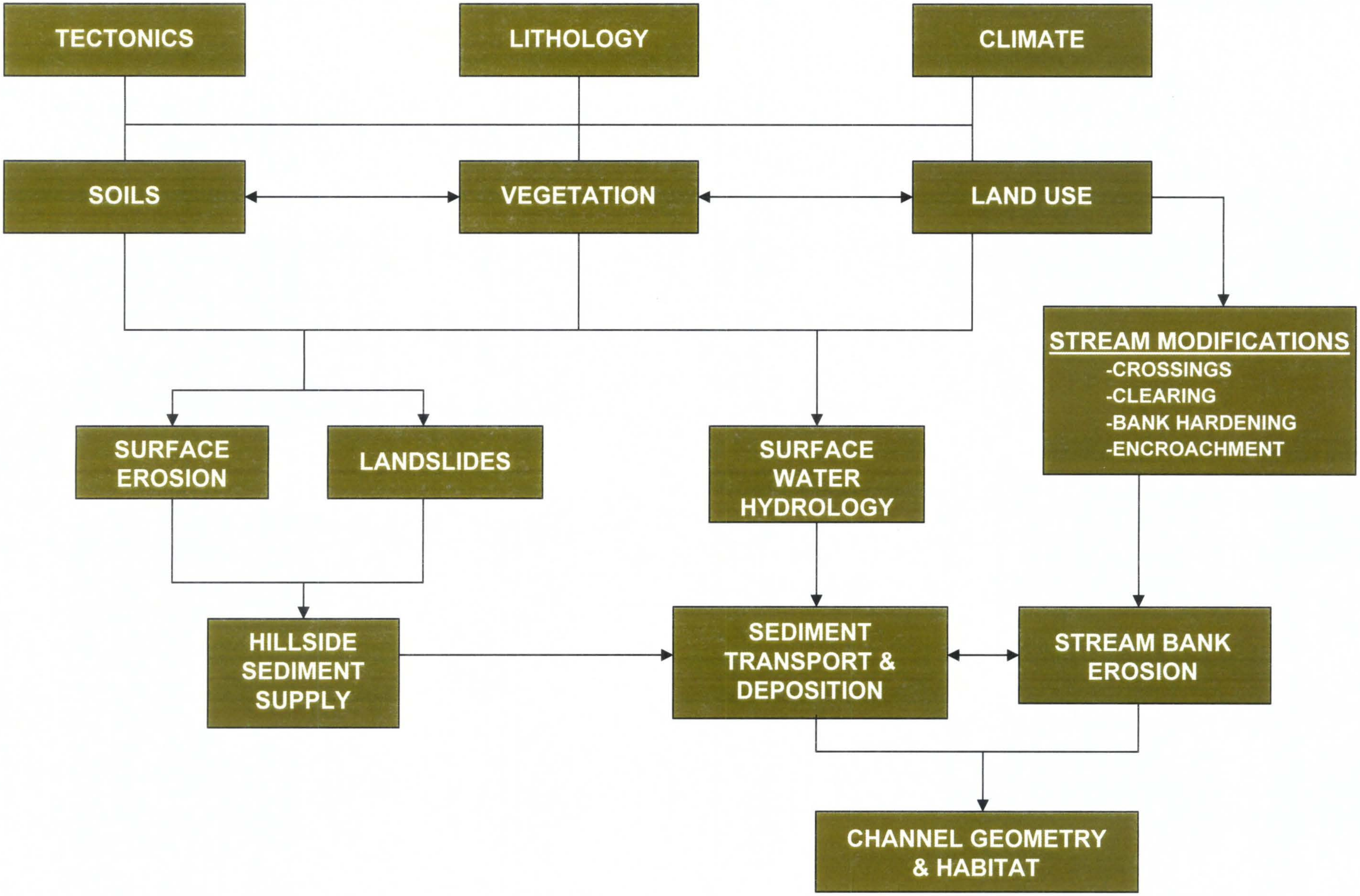
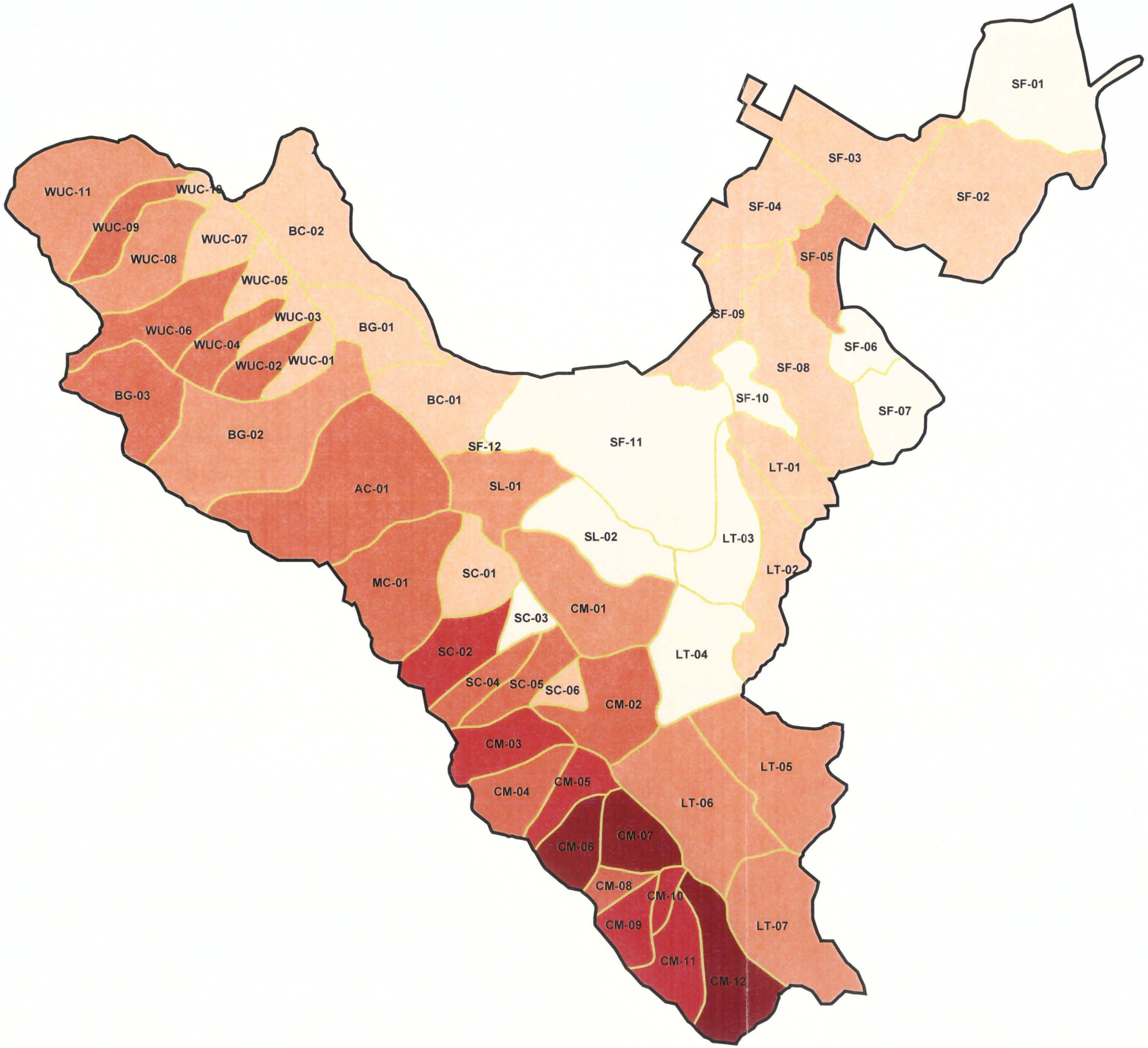


FIGURE 4. Conceptual Model of Erosion in San Francisquito Creek

Figure 6 Natural Erosion in Sub-subwatersheds in the San Francisquito Watershed



Legend

▭ Watershed Boundary

▭ Sub-Sub Watershed Boundary

Average Erosion Rate in Cubic Yards / Acre

- ▨ 0 - 0.1
- ▨ 0.1 - 0.5
- ▨ 0.5 - 1.0
- ▨ 1.0 - 5.0
- ▨ 5.0 - 10.0
- ▨ 10 - >10

N

Scale 1 : 72,000

0 3,000 6,000 9,000 12,000

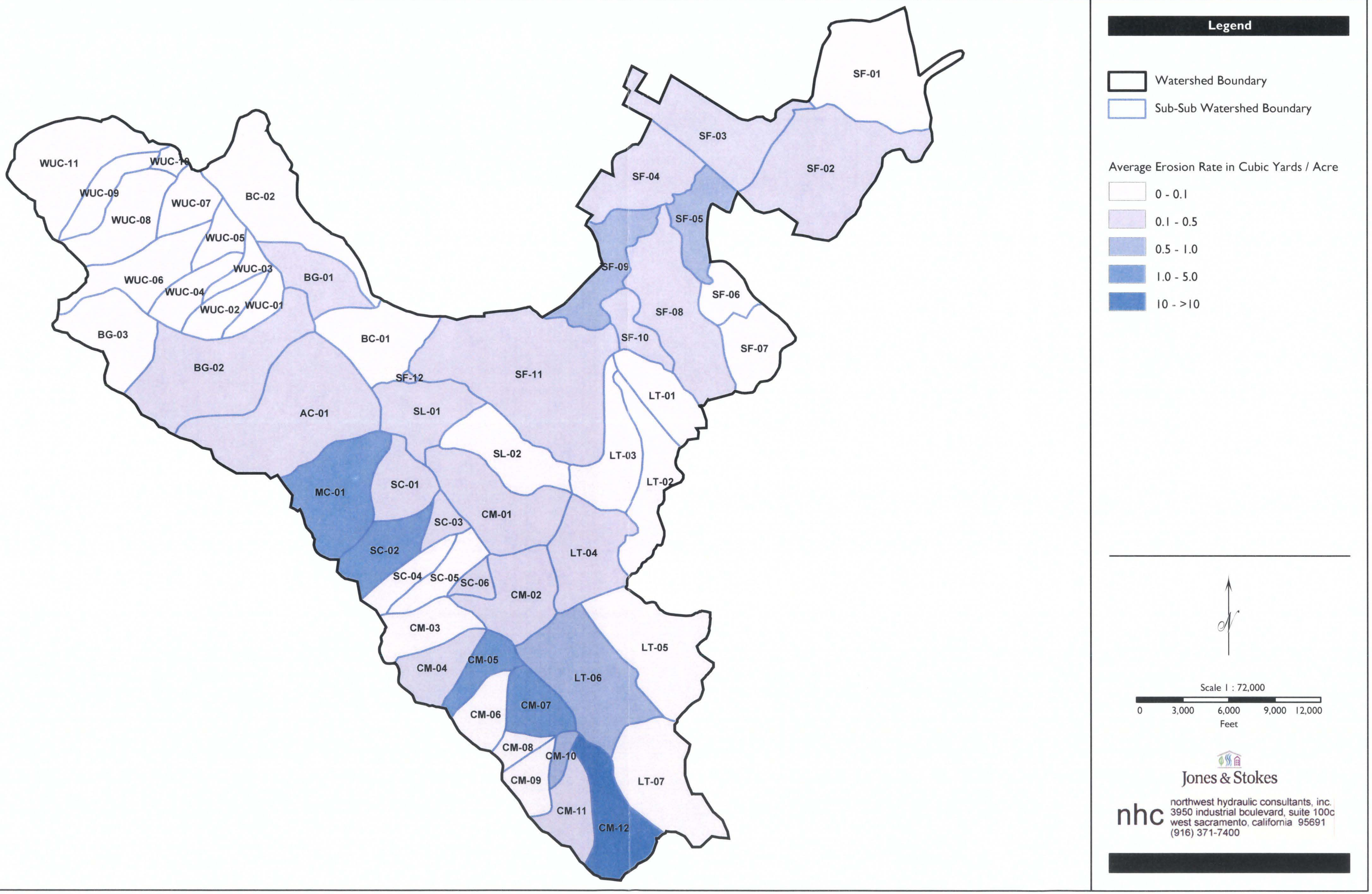
Feet

Jones & Stokes

nhc northwest hydraulic consultants, inc.
3950 industrial boulevard, suite 100c
west sacramento, california 95691
(916) 371-7400

N: / NHC / 03003.03 / ARCMAP / NATURAL_EROSION_17X11.MXD (11.20.03) CN

Figure 7 Human - related Erosion in Sub-subwatersheds in the San Francisquito Watershed

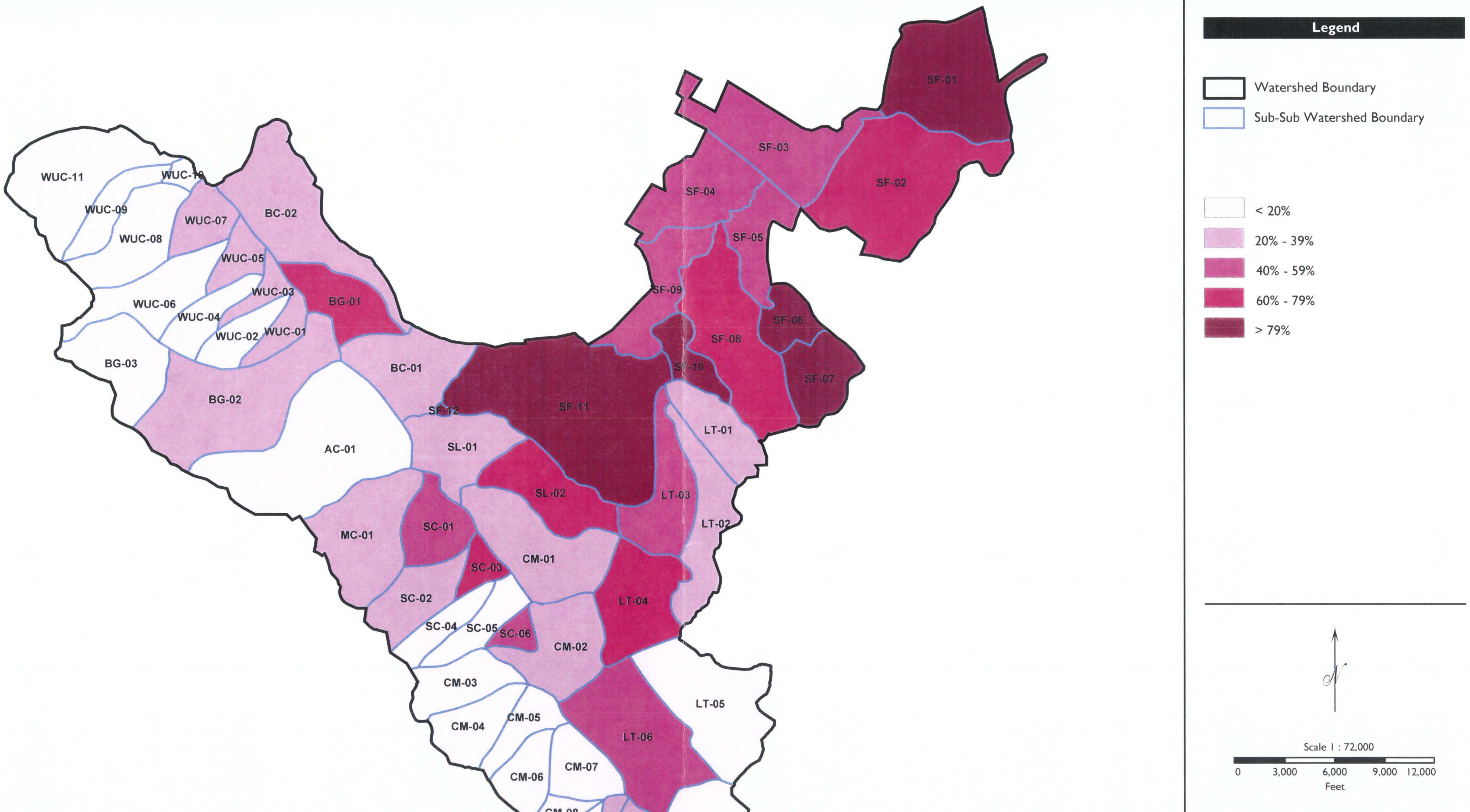


Jones & Stokes

nhc northwest hydraulic consultants, inc.
3950 industrial boulevard, suite 100c
west sacramento, california 95691
(916) 371-7400

N: / NHC / 03003.03 / ARCMAP / HUMAN_EROSION_17X11.MXD (11.20.03) CN

Figure 8 Human - related Erosion as a Percentage of Total Erosion in the San Francisquito Watershed



Jones & Stokes

nhc
northwest hydraulic consultants, inc.
3950 industrial boulevard, suite 100c
west sacramento, california 95691
(916) 371-7400

N:/NHC/03003.03/ARCMAP/HUMAN_RELATED_PERCENT_17X11.MXD (11.20.03) CN

Appendix A: Summary of Stream Channel Observations
Searsville Lake, Bear, Los Trancos and San Francisquito Creek Subwatersheds

				Channel Character					Bed Material (mm)		Banks			Sediment Transport and Deposition	
Stream and Site	Sub-Sub watershed	Site #	Stream Type	Slope (%)	Bankfull Width (ft)	Bankfull Depth (ft)	D_{50}	D_{90}	Description	Comment	Left Bank	Right Bank	Channel Incision	Erosion	Storage and Deposition
Corte Madera Creek															
downstream of Alpine Road crossing	CM-12	CM-01	step-pool	N/A	12 to 15	3 to 4	N/A	N/A	conglomerate boulders to 500 mm on riffles	boulder steps sit on poorly indurated bedrock	valley wall - sandy colluvium over bedrock	sand over boulders; 3 to 5 ft	Incision of 2 or 3 feet recently; up to 6 feet downstream of culvert outlet	small landslide from stream undercutting; irregular bank erosion; poss avulsion	frequent lateral bars of sand and gravel; pools filled with sand and pebbles up to 1 foot thick
At first bridge downstream of Closed Section of Alpine Road	CM-07	CM-02	pool-riffle	3 to 4	about 25	about 2	N/A	N/A	cobbles and boulders	lateral and point bars	sand over gravel - 2 feet high	sand over gravel - 2 feet high	less than 1 foot recently	bank trimming; roots exposed, minor widening	Minor storage in lateral bars and pools
At second bridge downstream of Closed Section of Alpine Road	CM-07	CM-03	pool-riffle	N/A	25 to 30	N/A	N/A	N/A	cobbles and boulders	lateral bars of gravel and sand	colluvium - 10 feet high	colluvium - 10 feet high; rock from Alpine Road	none observed	bank trimming; roots exposed, minor widening	Minor storage in lateral bars and sand in pools
mouth of Damiani Creek	CM-06	CM-04	step-pool	N/A	20	about 5	N/A	N/A	cobbles; gravel and sand	LWD and old stumps in bed	debris flow lobe; 6 feet high	debris flow lobe; 6 feet high	incising into debris flow lobe or deposit; rate slowed by LWD	banks steep and bare	little storage in channel through deposit; storage of coarse material upstream
Bridge over Creek to Skyline Ridge	CM-05	CM-05	boulder riffles	N/A	20 to 25	about 3	N/A	N/A	boulder cobble; riffles to 300 mm		alluvium over boulders	alluvium over boulders; toe of Alpine Road fill upstream	Incision of about 5 to 6 feet below bridge apron; maybe one or two feet recent (?); little or no disturbance upstream	eroding fill slope for Alpine Road above bridge	lateral and medial bars; gravel in boulder riffles and in pools
Bridge at entrance to Windy Hill Open Space Preserve	CM-02	CM-06	pool-riffle	N/A	about 15	3 to 5	N/A	N/A	boulder riffles	riffles seem very compact and stable	alluvium over gravel	alluvium over bedrock; 10 to 20 ft high	recent incision minor; terraces along channel	erosion on bends and opposite bars	plentiful sand and gravel storage on bars, channel margins and in pools
Upstream of the mouth of Hamms Creek	CM-03	CM-11	pool-riffle	N/A	20 to 25	about 3	N/A	N/A	gravel and cobble	bed filled with gravel	10 to 15 feet of alluvium	10 feet of alluvium	No recent incision	on outside of bend; erosion/small landslide	section appears to be aggrading; cobble bed filled with gravel and sand
Downstream of Bridge to Open Space lands near Willowbrook and Alpine Rds	CM-02	CM-12	pool-riffle	N/A	about 20	3 to 5	N/A	N/A	cobble riffles		20 to 25 feet of alluvium	20 to 25 feet of alluvium	No recent incision; terraces at two levels above channel bed	past erosion opposite bar on shallow bend	cobbles aggrading in stream and on small lateral bars
at Willowbrook Road Bridge near Portola	CM-02	CM-07	pool-riffle	N/A	about 20	3 to 5	N/A	N/A	compact cobble and gravel; lateral sand and gravel bars	clasts up to 200 mm moved recently	N/A	N/A	No recent incision	reasonably stable low; developing a sinuous pattern	sand and gravel aggradation
At Westridge Road Bridge	CM-01	CM-10	pool-riffle	N/A	20 to 25	about 3	40	100	bar head material; sand and gravel	clasts up to 150 mm moved recentlly	about 20+ feet	20 feet of dense sand	no recent incision; at least two terraces visible	on outside of bends; gabion protection at some properties	sand and gravel up to foot thick in pools; on bar tops
Bear Creek															
Bear Gulch at Woodside Road	BG-02	BG-01	step-pool	N/A	N/A	N/A	N/A	N/A	boulders and cobbles	steps appear to be degraded	3 to 5 ft of sand over boulders	wall	incised below bridge apron; elevated flood channel	on outside of bends	very limited; small cobble bars
West Union Above Woodside Road to Tripp Road	WUC-01	WU-01	pool-riffle	N/A	N/A	N/A	N/A	N/A	cobble boulder riffles	long riffles and short pools	N/A	sand over gravel; 20 to 30 feet	possible recent minor incision	sacrete wall underscoured; erosion on outside of bends	cobbles bars; minimal sand in pools
Bear Creek Downstream of Sand Hill Road (Jasper Ridge)	BC-01	B-01	pool-riffle	0.5	25	3 to 5	60	100	bar head (mobile) material	cobble riffles up to 250 mm (seem stable)	sand over gtravel -- 5 feet	sand over gravel; 10 feet	no recent incision; fan surface is now terrace	around logjam and opposite bars -- minor	deep sand in pool below Sand Hill Road up to 1 foot; small lateral bars.
Los Trancos Creek															
At Second Upstream Crossing of Los Trancos Road	LT-03	LT-03	plane bed	3 to 4	15	3 to 4	N/A	300 to 400	boulder bed; conglomerate	bed filled with sand and pebbles; angular gravel in culvert barrel	N/A	road fill and protection	no recent incision	minor erosion	appears to be aggrading with coarse material; up to 0.2 feet of sand and pebbles
At Arastradero Road	LT-03	LT-02	pool-riffle	1.5 to 2	24	3	40	85	bar head (mobile) material	active transport; material to 150 mm	gravel to 2.5 ft above bed; sand	N/A	no recent incision	opposite bars; on bends. Eroding ditch carries fines to stream	sand in pools up to 0.5 to 1 foot deep; gravel point bars; cobble fill below bridge
at Piers Lane	LT-03	LT-01	bedrock	N/A	N/A	N/A	N/A	N/A	boulders and cobbles over bedrock		N/A	sand over boulders/bedrock	low weir/dam at head of reach; incision into bedrock to match SF Creek (?). Low terraces	minor erosion; inside of bend recently repaired?	sand and gravel to 1 foot in poosl near mouth; backwater deposits.
San Francisquito Creek															
Downstream of Bear Creek and Concrete Ford -- Jasper Ridge	SF-11	SF-01	bedrock	N/A	N/A	N/A	N/A	N/A	cobbles over bedrock		alluvium over bedrock -- 15 feet	alluvium over bedrock -- 15 feet	incision into bedrock	none observed	gravel and sand to 1 foot in bedrock pools; large gravel bars downstream at powerline crossing
Bridge crossing at Webb Ranch Home	SF-11	SF-02	pool-riffle	N/A	40	8	N/A	N/A	gravel/cobble riffles; sandy gravel over bed material	bedrock exposure in bed	dense sand to 20 feet	dense sand to 20 feet	no recent incision	minor erosion	No instream bars; deposit of sandy gravel below bridge on bed
Above Los Trancos Creek (Alpine Road)	SF-11	SF-03	pool-riffle	N/A	N/A	N/A	N/A	N/A	cobble-boulder riffles	bedrock exposure in bed at bridge	sand over cobbles and boulders	sand over cobbles and boulders	concrete apron on pier has failed; no obvious recent incision	none observed	left barrel of bridge filled with sand and gravel to about 5 feet above bed; minor sand accumulation in pools; junction bar near mouth of Los Trancos of cobbles and gravel

Appendix B: Sediment Budget Searsville Lake Watershed
Years 1995 to 2000

Sub-Watershed	**CM1**	**CM2**	**CM3**	**CM4**	**CM5**	**CM6**	**CM7**	**CM8**	**CM9**	**CM10**	**CM5/7**	**CM11**	**CM12**		**AC1**	**MC1**	**SC1**	**SC2**	**SC3**	**SC4**	**SC5**	**SC6**	**SL1**	**SL2**		
PHYSICAL CHARACTERISTICS	Corte Madera	Corte Madera	Hamms	Jones	Creek A	Damiani	Creek B	Rengstorff	Coal	Corte Madera	Middle CM	Creek C	Uppe Corte M	*Subtotal*	Alam-bique	Martin	Upper Sausal	Bull Run	Unnamed	Neils	Bozzo	Sausal	West Ridge	West Ridge	*Subtotal*	***Grand Total***
Area (acres)	811	589	378	361	251	283	337	117	237	86	-	357	560	*4,367*	1492	790	381	409	138	231	280	107	523	556	*4,907*	***9,274***
Stream Length (feet)	8810	7459	6976	5905	3497	3969	5682	2808	3215	1446	12100	5745	7253	*74,865*	13524	8420	4798	8151	3414	5938	5864	2060	3082	11049	*66,300*	***141,165***
Road Length paved (mi)	10.4	9.5	0	2.7	0.9	0.9	2.2	1.1	1.8	0.5	-	2.6	3.1	*36*	7.2	8.9	4.6	2.9	2.3	0.5	0.7	0.7	2.6	4.4	*35*	***71***
Road Length native (mi)	1	2	1.4	1.8	0.6	0.8	1.7	0	0.1	0.2	-	1.8	3.7	*15*	11.6	2.9	1.6	3.6	0.8	1.2	0.8	0.5	3.5	0.9	*27*	***43***
Total Road Length (mi)	11.4	11.5	1.4	4.5	1.6	1.8	3.8	1.2	1.8	0.7	-	4.4	6.8	*51*	18.8	11.8	6.3	6.6	3.1	1.6	1.6	1.3	6.1	5.3	*63*	***113***
STREAM EROSION																										
Percent Severe Bank Erosion (%)	0.398	0.386	0.447	0.434	0.479	0.588	0.374	0.25	0.421	0.559	0.237	0.633	0.934		0.197	0.141	0.069	0.148	0.005	0.162	0.162	0.069	0.005	0.005		
Percent Moderate Bank Erosion (%)	0.183	0.304	0.391	0.361	0.273	0.163	0.549	0.15	0.269	0	0.304	0.303	0.061		0.215	0.42	0.176	0.45	0.005	0.177	0.177	0.176	0.01	0.01		
Incised Length (feet)	0	1640	0	984	0	0	656	0	0	0	4000	984	0	*8,264*	6560	4592	0	1000	0	1000	1000	0	0	0	*14,152*	***22,416***
Incised Volume (yd^3)	0	492	0	295	0	0	197	0	0	0	2680	295	0	*3,959*	1968	1378	0	300	0	300	300	0	0	0	*4,246*	***8,205***
Net Stream Erosion (yd^3)	1564	1870	1520	1533	765	998	1359	323	628	323	4195	1924	2754	*19,757*	3324	2206	217	1149	9	790	784	93	9	33	*8,614*	***28,372***
Human-Caused Component (yd^3)	391	468	0	0	191	0	340	0	0	81	1049	0	0	*2,519*	0	552	0	287	0	0	0	47	0	17	*902*	***3,421***
STREAM DEPOSITION																										
Percent Aggraded (%)	1	1	0.382	0.315	0.602	0.588	0.689	0.5	0.539	0.5	0.642	0.732	1		0.336	0.3	0.4	0.45	0.4	0.458	0.458	0.71	0.224	0.224		
Net Stream Storage (yd^3)	(1322)	(1119)	(400)	(279)	(316)	(350)	(587)	(211)	(260)	(108)	(1165)	(631)	(1088)	*(7,835)*	(682)	(379)	(288)	(550)	(205)	(408)	(403)	(219)	(104)	(371)	*(3,608)*	***(11,444)***
LANDSLIDE EROSION																										
No of Small Landslides	8	8	38	30	22	51	19	5	18	4	11	45	81	*340*	47	25	0	34	0	12	14	0	1	0	*133*	***473***
Area of Small Landslides (acres)	0.3	0.3	1.4	1.0	0.9	1.8	1.0	0.2	1.1	0.2	0.5	2.0	9.2	*20*	3.27	2.16	0	1.26	0	0.46	0.5	0	0.17	0	*8*	***28***
Small Landslide Erosion (yd^3)	2,000	2,065	9,033	6,323	6,065	11,678	6,400	1,290	6,904	1,161	3,123	12,775	59,294	*128,111*	21098	13936	0	8130	0	2968	3226	0	1097	0	*50,455*	***178,566***
Human-caused Component (yd^3)	500	516	0	0	1,516	0	1,600	0	0	290	781	0	0	*5,204*	0	3484	0	2032	0	0	0	0	0	0	*5,516*	***10,720***
No of Big Landslides	0	1	0	0	1	0	7	0	0	0	-	1	11	*21*	0	3	0	6	0	0	0	0	0	0	*9*	***30***
Big Landslide Erosion (yd^3)	0	600	0	0	600	0	4,200	0	0	0	-	600	6,600	*12,600*	0	1800	0	3600	0	0	0	0	0	0	*5,400*	***18,000***
No Air Photo Landslides - Natural	0	0	0	1	3	3	7	0	1	0	-	0	7	*22*	0	0	0	0	0	0	0	0	0	0	*0*	***22***
Area of Natural Landslides (acres)	0.0	0.0	0.0	0.1	0.5	1.2	1.9	0.0	0.1	0.0	-	0.0	2.4	*6.1*	0	0	0	0	0	0	0	0	0	0	*0*	***6***
AP Landslide Erosion - Natural (yd^3)	0	0	0	598	3,984	9,363	15,538	0	598	0	-	0	19,323	*49,403*	0	0	0	0	0	0	0	0	0	0	*0*	***49,403***
No Air Photo Landslides - ManMade	0	0	0	0	0	0	1	0	0	0	-	0	3	*4*	0	0	0	0	0	0	0	0	0	0	*0*	***4***
Area of ManMade Landslides (acres)	0	0	0	0	0	0	0.3	0	0	0	-	0	3.5	*3.8*	0	0	0	0	0	0	0	0	0	0	*0*	***4***
AP Landslide Erosion - ManMade (yd^3)	0	0	0	0	0	0	2,390	0	0	0	-	0	28,287	*30,677*	0	0	0	0	0	0	0	0	0	0	*0*	***30,677***
SURFACE EROSION (yd^3)																										
Paved Road Erosion	146	133	0	38	13	13	31	15	25	7	-	36	43	*500*	101	125	64	41	32	7	10	10	36	62	*487*	***987***
Unpaved Road and Trail Erosion	55	110	77	99	33	44	94	0	6	11	-	99	204	*831*	638	160	88	198	44	66	44	28	193	50	*1,507*	***2,338***
Scar Erosion -- Natural	25	26	112	84	115	238	233	16	92	14	-	158	927	*2,040*	262	173	0	101	0	37	40	0	14	0	*626*	***2,665***
Scar Erosion -- Man-made	0	0	0	0	0	0	24	0	0	0	-	0	281	*304*	0	0	0	0	0	0	0	0	0	0	*0*	***304***
Slide Scarp Retreat -- Natural	2	2	4	4	4	6	6	2	4	1	-	5	12	*50*	6	5	0	4	0	2	2	0	1	0	*21*	***71***
Slide Scarp Retreat -- Man-Made	0	0	0	0	0	0	2	0	0	0	-	0	6	*8*	0	0	0	0	0	0	0	0	0	0	*0*	***8***
Sheet Erosion	57	41	27	25	18	20	24	8	17	6	-	25	39	*307*	105	56	27	29	10	16	20	8	37	39	*345*	***652***
GULLY EROSION																										
Estimated Gully Length (ft)	17,953	11,978	5,498	6,008	4,786	5,370	5,439	1,053	4,606	1,392	-	6,036	11,227	*81,346*	35,712	17,650	7,775	5,346	1,140	1,685	3,376	1,471	14,177	7,299	*95,631*	***176,977***
Gully Wall Erosion (yd^3)	479	319	147	160	128	143	145	28	123	37	-	161	299	*2,169*	952	471	207	143	30	45	90	39	378	195	*2,550*	***4,719***
Human-caused Component (yd^3)	158	105	48	53	42	47	48	9	41	12	-	53	99	*716*	314	155	68	47	10	15	30	13	125	64	*842*	***1,557***
TOTAL HUMAN-CAUSED	1,307	1,374	152	215	2,728	124	5,466	33	88	407	1,829	214	28,959	*41,066*	1,158	4,531	248	2,634	96	104	103	104	390	231	*9,599*	***50,665***
TOTAL NATURAL	3,020	3,793	10,767	8,649	11,741	25,123	24,979	1,650	8,307	1,154	5,488	15,570	89,110	*203,862*	25,328	14,400	356	10,759	29	3,827	4,113	73	1,374	147	*60,406*	***264,268***
TOTAL EROSION	4,327	5,166	10,919	8,864	11,724	22,502	30,445	1,683	8,395	1,562	7,318	15,784	118,069	*246,758*	26,486	18,931	603	13,393	125	3,931	4,216	177	1,765	378	*70,005*	***316,763***
ADJUSTED FOR DEPOSITION	3,005	4,048	10,519	8,585	11,408	22,152	29,858	1,472	8,135	1,453	6,152	15,153	116,981	*238,923*	25,805	18,552	316	12,843	(80)	3,523	3,813	(42)	1,661	7	*66,397*	***305,319***
eroded material as % of total	1.4%	1.6%	3.4%	2.8%	3.7%	7.1%	9.6%	0.5%	2.7%	0.5%	2.3%	5.0%	37.3%		8.4%	6.0%	0.2%	4.2%	0.0%	1.2%	1.3%	0.1%	0.6%	0.1%		
Natural Erosion (yd^3/acre)	0.74	1.29	5.70	4.79	9.36	17.75	14.82	2.82	7.01	2.68		8.72	31.82	9.34	3.40	3.65	0.19	5.26	0.04	3.31	2.94	0.14	0.53	0.05	2.46	5.70
Man-Made Erosion (yd^3/acre)	0.32	0.47	0.08	0.12	2.17	0.09	3.24	0.06	0.07	0.95		0.12	10.34	1.88	0.16	1.15	0.13	1.29	0.14	0.09	0.07	0.19	0.15	0.08	0.39	1.09
Total Erosion (yd^3/acre)	1.07	1.75	5.78	4.91	11.53	17.84	18.07	2.88	7.08	3.63		8.84	42.17	11.22	3.55	4.79	0.32	6.55	0.18	3.40	3.01	0.33	0.67	0.14	2.85	6.79

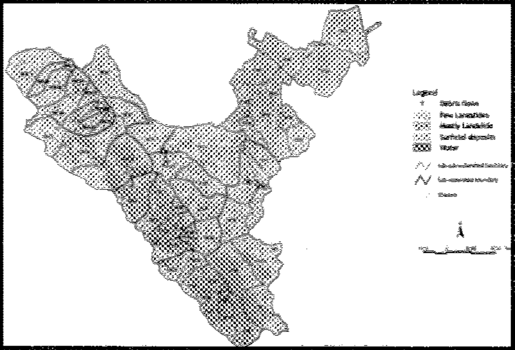
Appendix C: Sediment Budget Los Trancos & Bear Creeks
Years 1995 to 2000

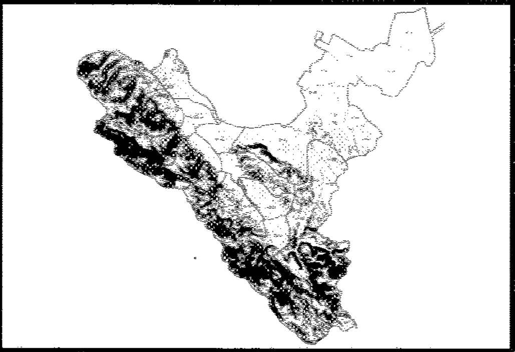
	LT1	LT2	LT3	LT4	LT5	LT6	LT7		BC-1	BC-2	BG-1	BG-2	BG-3	WUC-1	WUC-2	WUC-3	WUC-4	WUC-5	WUC-6	WUC-7	WUC-8	WUC-9	WUC-10	WUC-11		
Subwatershed	*Los Trancos*	*Los Trancos*	*Los Trancos*	*Los Trancos*	*Buckeye Ck*	*Los Trancos*	*Los Trancos*	*Subtotal*	*Bear Creek*	*Bear Creek*	*Bear Gulch*	*Bear Gulch*	*Bear Gulch*	*West Union*	*Appletree Gulch*	*West Union*	*Tripp Gulch*	*West Union*	*Squealer Gulch*	*West Union*	*McGarvey Gulch*	*West Union*	*West Union*	*West Union*	*Subtotal*	*TOTAL*
PHYSICAL CHARACTERISTICS																										
Area (acres)	405	555	534	649	920	1000	807	**4,870**	618	964	428	1239	583	170	242	139	271	192	528	281	543	272	64	875	**7,409**	**12,279**
Stream Length (feet)	8771	13049	16010	10225	15138	14723	9313	**87,229**	5537	19115	8838	17713	12092	1558	6556	2215	7313	3179	12872	3895	9343	7468	2068	16781	**136,543**	**223,772**
Road Length paved (mi)	3.7	2.7	6.7	8.0	5.1	6.4	3.4	**36**	7.8	18.2	5.9	2.3	0.6	1.7	1.0	1.7	0.9	2.1	4.3	2.2	0.6	0.1	0.0	0.8	**50**	**86**
Road Length native (mi)	0.8	1.0	1.2	1.4	4.3	3.6	2.5	**15**	1.6	0.7	0.5	4.2	2.8	0.7	0.1	0.0	0.0	0.2	2.1	2.1	3.9	0.7	0.1	0.2	**20**	**35**
Total Road Length (mi)	4.5	3.7	7.9	9.4	9.4	10.0	5.9	**51**	9.4	18.9	6.4	6.5	3.4	2.4	1.1	1.7	0.9	2.3	6.4	4.3	4.5	0.8	0.1	1.0	**70**	**121**
STREAM EROSION																										
Percent Severe Bank Erosion (%)	0.042	0.036	0.028	0.013	0.005	0.032	0.162		0.074	0.031	0.079	0.256	0.249	0.024	0.252	0.025	0.344	0.073	0.188	0.088	0.214	0.169	0.076	0.230		
Percent Moderate Bank Erosion (%)	0.092	0.083	0.070	0.042	0.021	0.077	0.232		0.136	0.075	0.142	0.316	0.310	0.062	0.313	0.064	0.387	0.135	0.256	0.153	0.280	0.238	0.138	0.294		
Incised Length (feet)	0	0	0	0	0	0	0	**0**	0	0	4419	8857	0	0	0	0	0	0	0	0	0	0	0	0	**13,276**	**13,276**
Incised Volume (yd^3)	0	0	0	0	0	0	0	**0**	0	0	663	1328	0	0	0	0	0	0	0	0	0	0	0	0	**1,991**	**1,991**
Net Stream Erosion (yd^3)	228	296	291	96	62	302	820	**2,095**	239	380	1068	3702	1579	25	866	36	1289	136	1297	197	1061	683	91	2037	**14,687**	**16,782**
Human-caused Component (yd^3)	0	0	73	24	0	75	0	**172**	60	95	764	1328	0	6	0	9	0	34	0	0	0	0	0	0	**2,297**	**2,469**
STREAM DEPOSITION																										
Percent Aggraded (%)	0	0	0.5	0.5	0.5	0	0	**2**	0.25	0.25	0.25	0	0	0.25	0	0.25	0	0.25	0	0	0	0	0	0		
Net Stream Storage (yd^3)	0	0	(736)	(470)	(696)	0	0	(1,903)	(202)	(440)	(203)	0	0	(36)	0	(51)	0	(73)	0	0	0	0	0	0	**0**	(1,903)
LANDSLIDE EROSION																										
No of Small Landslides	0	0	0	0	0	0	0	**0**	0	0	0	5	6	0	5	0	5	0	6	0	5	6	0	6	**44**	**44**
Area of Small Landslides (acres)	0.00	0.00	0.00	0.00	0.00	0.00	0.00	**0**	0.000	0.000	0.000	0.175	0.210	0.000	0.175	0.000	0.175	0.000	0.210	0.000	0.175	0.210	0.000	0.210	**1.5**	**2**
Small Landslide Erosion (yd^3)	0	0	0	0	0	0	0	**0**	0	0	0	1129	1355	0	1129	0	1129	0	1355	0	1129	1355	0	1355	**9,936**	**9,936**
Human-caused Component (yd^3)																										
No of Big Landslides	0	0	0	0	0	0	0	**0**	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	**0**	**0**
Big Landslide Erosion (yd^3)	0	0	0	0	0	0	0	**0**	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	**0**	**0**
No Air Photo Landslides - Natural	0	0	0	0	1	4	4	**9**	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	**1**	**10**
Area of Natural Landslides (acres)	0	0	0	0	0.25	0.53	0.25	**1.0**	0.00	0	0	0.00	0.07	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	**0**	**1**
AP Landslide Erosion - Natural (yd^3)	0	0	0	0	1991	4281	1991	**8,264**	0	0	0	0	597	0	0	0	0	0	0	0	0	0	0	0	**597**	**8,861**
No Air Photo Landslides - ManMade	0	0	0	2	0	1	0	**3**	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	**0**	**3**
Area of ManMade Landslides (acres)	0	0	0	0.07	0	0.44	0	**0.5**	0	0	0	0.00	0.00	0	0	0	0	0	0	0	0	0	0	0	**0**	**1**
AP Landslide Erosion - ManMade (yd^3)	0	0	0	597	0	3584	0	**4,182**	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	**0**	**4,182**
SURFACE EROSION																										
Paved Road Erosion	52	38	94	112	71	90	48	**504**	109	255	83	32	8	24	14	24	13	29	60	31	8	1	0	11	**703**	**1,207**
Unpaved Road and Trail Erosion	44	55	66	77	237	198	138	**814**	88	39	28	231	154	39	6	0	0	11	116	116	215	39	6	11	**1,095**	**1,909**
Scar Erosion -- Natural	0	0	0	0	20	42	20	**82**	0	0	0	14	23	0	14	0	14	0	17	0	14	17	0	17	**129**	**211**
Scar Erosion -- Man-made	0	0	0	6	0	36	0	**41**	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	**0**	**41**
Scarp Erosion -- Natural	0	0	0	0	2	2	2	**6**	0	0	0	1	2	0	1	0	1	0	2	0	1	2	0	2	**12**	**18**
Scarp Erosion -- Man-made	0	0	0	1	0	2	0	**3**	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	**0**	**3**
Sheet Erosion	28	39	38	46	65	70	57	**342**	43	68	30	87	41	12	17	10	19	14	37	20	38	19	5	62	**521**	**863**
GULLY EROSION																										
Estimated Gully Length (ft)	4,594	5,266	1,612	11,192	15,222	18,277	17,318	**73,481**	14,857	12,697	5,286	23,174	7,147	4,052	1,430	2,372	1,630	3,157	4,552	5,378	8,576	1,508	44	12,094	**107,954**	**181,435**
Gully Wall Erosion (yd^3)	123	140	43	298	406	487	462	**1,959**	396	339	141	618	191	108	38	63	43	84	121	143	229	40	1	323	**2,879**	**4,838**
Human-caused Component (yd^3)	37	42	13	90	122	146	139	**588**	119	102	42	0	0	32	11	19	13	25	36	43	69	12	0	97	**621**	**1,209**
TOTAL HUMAN-CAUSED	161	174	283	952	494	4,202	380	**6,647**	419	558	947	1,679	203	113	48	62	45	113	249	209	330	71	10	180	**5,236**	**11,883**
TOTAL NATURAL	314	395	249	281	2,359	4,894	3,156	**11,646**	457	522	402	4,136	3,747	94	2,037	72	2,464	161	2,756	297	2,366	2,084	92	3,636	**25,323**	**36,969**
TOTAL EROSION	475	568	532	1,233	2,853	9,095	3,536	**18,293**	876	1,080	1,349	5,815	3,950	207	2,085	133	2,509	274	3,005	506	2,696	2,155	103	3,817	**30,559**	**48,852**
ADJUSTED FOR DEPOSITION	475	568	(205)	763	2,157	9,095	3,536	**16,390**	674	640	1,146	5,815	3,950	171	2,085	82	2,509	201	3,005	506	2,696	2,155	103	3,817	**29,554**	**45,944**
Total erosion as % of Watershed Total	2.6%	3.1%	2.9%	6.7%	15.6%	49.7%	19.3%		1.8%	2.2%	2.8%	11.9%	8.1%	0.4%	4.3%	0.3%	5.1%	0.6%	6.2%	1.0%	5.5%	4.4%	0.2%	7.8%		
Natural Erosivity (yd^3/acre)	0.77	0.71	0.47	0.43	2.56	4.89	3.91	2.39	0.74	0.54	0.94	3.34	6.43	0.55	8.42	0.51	9.09	0.84	5.22	1.06	4.36	7.66	1.44	4.16	3.42	3.01
Human-Related Erosivity (yd^3/acre)	0.40	0.31	0.53	1.47	0.54	4.20	0.47	1.36	0.68	0.58	2.21	1.35	0.35	0.66	0.20	0.44	0.16	0.59	0.47	0.74	0.61	0.26	0.16	0.21	0.71	0.97
Total Erosivity (yd^3/acre)	1.17	1.02	1.00	1.90	3.10	9.10	4.38	3.76	1.42	1.12	3.15	4.69	6.78	1.22	8.62	0.96	9.26	1.43	5.69	1.80	4.96	7.92	1.60	4.36	4.12	3.98

Appendix D. Sources of Information for Sediment Inflows and Sediment Deposition along San Francisquito Creek

Process	*Source*	*Time Period*	*Comment*
Sediment Inflows			
Los Trancos and Bear Creeks	Loads calculated at gage at Stanford Golf Course	Long-term average	Total suspended load and sand load from gaging programs by Porterfield (1980) and Brown and Jackson (1973). Gravel loads from HEC-6 Model developed by **nhc** et al (2002).
Searsville Lake	**nhc** et al (2002)	Long-term average	Fine sediment contribution with Searsville Dam in place is estimated to be 10% of volume deposited in reservoir
Small Tributaries	Crippen and Waananen (1969)	Early 1960s	Sediment yield roughly estimated for three tributaries prior to and during development
Incision of SF Creek	**nhc** et al (2002)	1964 to 1998	Incision of upper creek measured from changes in cross section areas
Bank Erosion along SF Creek	**nhc** et al (2002)	1964 to 1998	Erosion observed by comparing sections but volume has not been measured or estimated
Sediment Deposition			
Delta	Phillips (2000)	1930 to 2000	Cores of delta showing accumulation of sand on delta since mouth of SF creek was moved
Pope-Chaucer to Highway 101	**nhc** et al (2002)	1964 to 1998	Deposition from Pope-Chaucer to Highway 101 measured from changes in cross sections
Highway 101 to mouth	CRMP (1998)	1958 to 1993	Report on design of channel excavated in 1958 and infilling that has occurred since them. Channel dimensions not reported.
Sediment Excavation	SCVWD	1984 to present	Excavation volumes at Highway 101. Volumes not reported before 1984

Assessment
Existing Mgmt.
Practices





December 2003

San Francisquito Creek Watershed

Assessment of Existing Management Practices

DRAFT REPORT

Prepared for:

San Francisquito Creek
Joint Powers Authority

Prepared by:

nhc northwest hydraulic consultants
Leaders in water resource technology

Jones & Stokes

San Francisquito Creek
Watershed Analysis and Sediment Reduction Plan

Task 6
Assessment of Existing Management Practices

Draft Report
December 2003

Prepared for:
San Francisquito Creek
Joint Powers Authority

Prepared by:
Northwest Hydraulic Consultants
3950 Industrial Boulevard, Suite 100c
West Sacramento, CA 95691
Contact: Ken Rood
(916) 371-7400

Jones & Stokes Associates
2880 Zanker Road, Suite 210
San Jose, CA 95134

EXECUTIVE SUMMARY

The objectives of the Assessment of Existing Management Practices Task for San Francisquito Creek Watershed are to assess existing policies and regulations that provide erosion control or channel protection in the San Francisquito watershed, identify deficiencies, and recommend improvements. Our review was based on recent reports and publications that have examined land management policies and regulations for local jurisdictions in the watershed. Where practical, we updated or expanded the information in reports and documents through discussions with representatives of local governments or other agencies in the San Francisquito watershed.

The first step in the assessment was to develop a GIS of the boundaries of the jurisdictions in the San Francisquito Watershed. The GIS defined cities and towns (East Palo Alto, Palo Alto, Menlo Park, Woodside and Portola Valley), open spaces and parks (Mid Peninsula Regional Open Space District, San Mateo County Parks, Palo Alto Open Spaces and other preserves, parks or recreation areas) and incorporated areas of Santa Clara and San Mateo Counties. Stanford University, the largest private landowner, was also separately identified. The jurisdictional boundaries were then used to estimate, for each jurisdiction, recent sediment production, lengths of roads and trails on steep slopes, areas of debris flow sources and landslide deposits.

Our review focused on management of human-related erosion from landslides, streams and surface processes, both for new and for existing development. Previous reviews had addressed policies and regulations, and recommendations for improvements, for new private and public development. While new development can be a component of the human-related sediment contribution to streams, existing developments are usually more important or significant.

One important issue from the review is that an overall, watershed-wide agency seems to be needed for sediment management in the San Francisquito Watershed. Such an agency would coordinate efforts among the jurisdictions and help develop common standards. The focus for improvements in sediment management would be on stream erosion and rehabilitating roads and trails. Improved practices are required for managing and assessing alterations to hydrology from urban development and managing human impacts on stream banks. Bridges, culverts and encroachments contribute to erosion and incision and also create fish passage barriers. Better design standards for crossings are recommended and a program to mitigate or replace existing structures seems to be needed.

Unpaved roads and trails are important and ubiquitous sources of surface erosion in the upper watershed and they also contribute to initiation of landslides. A coordinated study is required to assess existing priority erosion areas and rehabilitate them. Development of common standards for trail construction and erosion control best management practices are also recommended.

TABLE OF CONTENTS

List of Tables iii
List of Figures iii
List of Appendices iii

1. INTRODUCTION 1

1.1. Objectives and Approach 1
1.2. Jurisdictions 1

2. SEDIMENT MANAGEMENT ISSUES 3

2.1. Human-Related Erosion by Jurisdiction 3
2.2. Sediment Contributions by Erosion Process 3

3. EXISTING POLICIES AND PRACTICES 10

3.1. Reviews of Policies and Practices 10
3.2. Other Policies or Practices 13

4. REVIEW AND RECOMMENDATIONS 16

4.1. Slope Failures 16
4.2. Stream Erosion 20
4.3. Surface Erosion (Roads and Trails) 22
4.4. Surface Erosion (Grading and Construction) 24
4.5. Gully Erosion 24

5. SUMMARY AND CONCLUSIONS 26

6. REFERENCES 28

List of Tables

1-1 Total Area in San Francisquito Watershed and Area by Subwatershed for Different Jurisdictions

2-1 1995 to 2000 Human-Related Sediment Contributions by Jurisdiction
2-2 Human-Related Erosion in the San Francisquito Creek Subwatersheds
2-3 Summary of Road and Trail Lengths Crossing Steep Slopes and Erosive Geologies

3-1 Sediment Management Measures Implemented by Jurisdictions in San Francisquito Creek Watershed in 2001

4-1 Summary of Recommended Sediment Management Practices

List of Figures

1. San Francisquito Watershed Jurisdictional Map
2. Human-related Erosion in the San Francisquito Sub-subwatersheds from 1995 to 2000
3. San Francisquito Creek Watershed Principal Predicted Debris Flow Source Areas per Jurisdiction
4. San Francisquito Creek Watershed Mostly Landslide Areas per Jurisdiction

List of Appendices

A. Paved Roads and Unpaved Roads and Trails by Jurisdiction

1. INTRODUCTION

1.1. Objectives and Approach

The objectives of Task 6 are to assess existing policies and regulations that provide erosion control or channel protection in the San Francisquito watershed, identify deficiencies, and recommend improvements. The Task 6 Memorandum is a key step in the development of a Sediment Reduction Plan for the San Francisquito Creek watershed.

Several reports and publications have recently assessed land management policies and regulations that provide sediment management or habitat protection for local jurisdictions in the San Francisquito Creek watershed and they form the basis of our review. Where practical, we have updated the information in reports and documents through discussions with representatives of local governments or other agencies in the San Francisquito watershed. The practices of some major landowners or managers (Stanford University, Mid Peninsula Regional Open Space District) are not assessed in existing documents or publications and we have contacted both organization in order to better understand their practices.

1.2. Jurisdictions

The San Francisquito Creek watershed is managed by a number of different jurisdictions. The watershed lies in both San Mateo and Santa Clara Counties. The watershed lies mostly in San Mateo County although about one-fifth of it, southeast of San Francisquito and Los Trancos creeks, lies in Santa Clara County. Figure 1 shows the boundary between the two counties along San Francisquito and Los Trancos Creeks.

The County division is important because each county administers the National Pollutant Discharge Elimination System (NPDES) permits for stormwater discharges to San Francisco Bay separately. Within Santa Clara County administration is by the Santa Clara Valley Urban Runoff Pollution Prevention Program (SCVURPPP) and within San Mateo County by the San Mateo Countywide Stormwater Pollution Prevention Program (SM-STOPPP). Palo Alto and the Santa Clara Valley Water District (SCVWD) are co-permittees with SCVURPPP; East Palo Alto, Menlo Park, Portola Valley and Woodside are co-permittees with SM-STOPPP. The two administrative groups have different NPDES permit requirements and different approaches to meeting their permits.

Figure 1 shows the areas where local governments have jurisdiction, including the cities of East Palo Alto, Palo Alto, and Menlo Park, and the towns of Woodside and Portola Valley. San Mateo and Santa Clara Counties are responsible for unincorporated areas and County Parks that lie outside of the boundaries of these cities and towns. Figure 1 also shows the area owned by Stanford University in the central part of the watershed and the regional greenbelt managed by the Mid Peninsula Regional Open Space District (MPROSD) in the upper watershed. Other significant landowners or managers include the Peninsula Open Space Trust, CalWater in upper Bear Gulch, and the Golden Gate Natural Recreation Area (Phleger Estate) in the upper West Union Watershed.

Table 1-1 summarizes the areas within San Francisquito Creek and its main tributary subwatersheds that are managed by each jurisdiction, as interpreted from the GIS shown on Figure 1.

Table 1-1: Total Area in San Francisquito Watershed and Area by Subwatershed for Different Jurisdictions

Jurisdiction	***Area by Subwatershed (acres)***				***Area in SF Watershed (acres)***
	Searsville	*Los Trancos*	*Bear*	*SF Creek*	
East Palo Alto	0	0	0	913	913
Palo Alto	0	1,778	0	1,673	3,451
Menlo Park	0	0	0	1,523	1,523
Portola Valley	2,967	1,023	0	175	4,165
Woodside	1,889	0	2,628	0	4,518
Santa Clara Unincorporated	0	134	0	0	134
San Mateo Unincorporated	1,457	443	1,869	39	3,808
Stanford	149	959	176	3,574	4,858
Jasper Ridge	418	0	0	352	769
CalWater	0	0	717	0	717
MPROSD	2,153	310	771	0	3,234
Golden Gate NRA	0	0	1,224	0	1,224
Peninsula Open Space Trust	240	145	10	0	395
Other	0	79	11	329	419
Total					*30,126*

Overall, Stanford University is the largest landowner in the San Francisquito Watershed. However, either San Mateo or Santa Clara County manages land use and issuing building permits on Stanford University lands. Organizations that are responsible for substantial areas in the San Francisquito watershed include Palo Alto, Portola Valley, Woodside, San Mateo County (unincorporated lands and County Parks) and the MPROSD.

2. SEDIMENT MANAGEMENT ISSUES

2.1. Human-Related Erosion by Jurisdiction

Figure 2 shows the contribution of human-related erosion to streams by sub-subwatershed for the period from 1995 to 2000 (see **nhc** and JSA 2003c). The figure identifies those sub-subwatersheds that have produced the most sediment per unit area and shows the concentration of erosion in the Santa Cruz Mountains. Average erosion rates for 1995 to 2000 for each of the larger jurisdictions included in Table 1-1 were estimated by overlaying the boundaries shown on Figure 1 onto the sub-subwatershed erosion map in Figure 2. Table 2-1 summarizes the results.

Table 2-1: 1995 to 2000 Human-related Sediment Contributions by Jurisdiction

Jurisdiction	*Erosion to Streams (yd^3/acre per year)*	*Comment*
East Palo Alto	0.1	
Palo Alto	0.2	Includes Foothills and Arastradero Parks
Menlo Park	0.4	
Stanford	0.3	Includes Jasper Ridge
MPROSD	1.1	
Portola Valley	0.6	
Woodside	0.3	
San Mateo County (Unincorporated)	1.0	Includes Huddart and Wunderlich Parks

The above estimates of human-related erosion required a number of assumptions that are described in the Sediment Analysis Memorandum (**nhc** and JSA 2003c). While there are considerable uncertainties in the erosion rates quoted above, the table does indicate that jurisdictions that lie in the upper watershed, along the Santa Cruz Mountains, have had the greatest recent human-related erosion. Long-term erosion rates from the different jurisdictions are not known and the relative contributions from the jurisdictions may differ when considered over several decades.

2.2. Sediment Contributions by Erosion Process

The Task 4.1 Historic Conditions and the Task 5 Sediment Analysis Memoranda described the nature, location, and relative importance of different erosion processes in the Los Trancos, Searsville Lake, Bear and San Francisquito subwatersheds (**nhc** and J&S 2003a, 2003c). Erosion in these subwatersheds has a natural and development-related component, where development often alters either where processes occur or how often they occur. The erosion processes potentially affected by development include landslides on hillslopes, stream erosion (including streamside landslides, bank erosion, and incision), and surface erosion (including surface wash from roads, construction sites, agriculture and other disturbed sites, and gully erosion). Table 2-2 on the following page summarizes the significant processes that contribute to human-related erosion in the major tributaries to San Francisquito Creek watershed. These are discussed in more detail in the following sections.

Table 2-2: Human-Related Erosion in the San Francisquito Creek Subwatersheds

Subwatershed	***Dominant Processes***	***Less Significant Processes***
Searsville Lake	Development-related landslides	Road erosion and stream bank modification also important
Los Trancos	Development-related landslides	Component of road erosion and gully erosion
Bear	Bank erosion in developed areas; incision on Bear Gulch	Gully erosion; component of road erosion and landslides
San Francisquito Creek	Bank erosion and incision along SF Creek from sediment trapping and bank modification	Erosion of developed lands in the upper subwatershed; erosion from urban areas

LANDSLIDES

As discussed in the Historic Conditions Memorandum, landslides in San Francisquito Creek are typically of two types – deep-seated landslides in bedrock and shallow debris slides and flows in surficial materials. Urban development and road construction on potentially unstable slopes can accelerate deep-seated landslides; road construction, drainage diversion, or clearing of vegetation or development on steep slopes may initiate debris slides and flows. While records are not complete, historic landslides associated with development have occurred in Woodside, Portola Valley, Ladera, subdivisions in upper Corte Madera Creek (Los Trancos Woods and Vista Verde), and along Alpine Road and Highway 84, roads in Los Trancos Woods, and along roads and trails in the upper Corte Madera and Los Trancos subwatersheds (see **nhc** and J&S 2003a). Observed human-related landslides from 1995 to 2000 were mostly in upper Corte Madera and Los Trancos watersheds and appeared to be caused by drainage diversion from roads and trails, often from private roads.

Figure 3 shows the distribution of debris flow source area by jurisdiction based on overlaying the jurisdictional boundaries onto the USGS map of source areas in San Francisquito Creek that was described in the Historic Conditions Report (**nhc** and JSA 2003a). Figure 4 shows the distribution of areas that are mostly landslide deposits, by jurisdiction, following a similar approach. The two figures show that the debris flow hazard areas are concentrated in San Mateo County, Mid Peninsula Regional Open Spaces, Portola Valley, and Palo Alto (Foothills Park), although those jurisdictions with area in the Santa Cruz Mountains typically have some source areas in their steep upper watersheds. Large landslide deposits, which are often associated with streamside landslides and sediment supply to streams (see Frey 2000), are mostly in San Mateo County, Portola Valley, MPROSD and Woodside.

The above suggests that the greatest potential for impacts of new development on landslides lie in unincorporated San Mateo County, Portola Valley and Woodside. While there are large source areas in MPROSD and San Mateo County Parks, little or no development is expected in these areas, eliminating the risk of human-related failure. An indication of the potential for landslides from existing development can be developed from the network of paved roads and unpaved roads and trails that lie in the jurisdictions with significant risk of debris flows or landslides. Table 2-3 summarizes the lengths of paved road and unpaved road and trail that cross steep slopes (greater than 35°) and have the greatest risk of initiating landslides. The analysis is based on querying the GIS database overlain by the jurisdiction boundaries (see definitions and description in **nhc** and JSA 2003a; also Appendix A).

Table 2-3: Length of Paved Road and Unpaved Road and Trail Crossing Steep Slopes

Jurisdiction	*Road and Trail on Steep Slopes (miles)*	
	Unpaved Roads and Trails	*Paved Roads*
San Mateo (Unincorporated)	1.97	0.91
Huddart Park	0.88	0.36
Wunderlich Park	3.65	0
MPROSD	2.07	2.19
Portola Valley	1.65	1.20
Palo Alto (Foothills Park)	0.65	0.11
Woodside	0.74	2.49

The above table only expresses part of the human-related landslide risk because it does not include structures or other developments other than roads. However, it does suggest that landslide risk from unpaved roads and trails is primarily in San Mateo County and it may be concentrated along about 20 miles of paved and unpaved road and trail.

STREAM EROSION

Stream erosion can be accelerated through at least five different development-related activities, as follows:

- Altering hydrology through creation of impervious area or other development modifications
- Modifying stream banks, particularly removing vegetation
- Encroaching onto floodplains or stream channels and altering local velocities and shear stresses
- Removing vegetation and woody debris from streams
- Trapping or removing coarse sediment.

Stream erosion, particularly bank erosion and channel incision, occurs throughout the San Francisquito Watershed. Particularly significant human-related incision, bank erosion or streamside landsliding has occurred in the upper Searsville Lake watershed along Corte Madera, in the Bear Creek watershed, and also along San Francisquito Creek.

Hydromodification (Peak Flows)
Increased peak flows from urban development or roads appear to play only a minor role in stream erosion in the upper San Francisquito Watershed. Effective impervious area from development appears to be too low to affect major streams in the Santa Cruz Mountains; however, some smaller watersheds may be affected. Westridge Creek likely has increased peak flows from low-density residential development and Bull Run and Martin Creek may also be affected.

Urban development has almost assuredly increased peak flows in San Francisquito Creek. Detailed modeling would be required to evaluate the magnitude and significance of the altered flows to bank erosion and stream adjustments. Small tributaries to the upper part of San Francisquito Creek also have more frequent peak flows following development, as documented by Crippen and Waananen (1969), with subsequent stream adjustments. It is not known if adjustments still continue in these small streams.

Hydromodification (Bank and Floodplain Disturbance)
nhc and JSA (2003b) indicate that about half of the area of riparian corridors in San Francisquito Creek are affected by residential or other development, primarily concentrated along streams in the lower part of the watershed. Bank erosion along San Francisquito Creek is thought to be partly or largely human-related, as a result of the peak flow modification discussed above, clearing of riparian vegetation or other bank modifications, construction of houses on top of the stream banks, and the sediment trapping discussed in the next section. San Francisquito Creek appears to be the greatest source of human-related bank erosion in the watershed.

Floodplain encroachments along Alpine Road and development in Portola Valley contribute to incision, bank erosion, and streamside landslides along Corte Madera Creek. Bridges and culverts also contribute to bank erosion and cause local channel incision by trapping bed material; knickpoints migrate upstream through Portola Valley when aprons below these structures fail. Poorly designed bank protection structures result in erosion of nearby banks and also contribute to sediment loads when they fail (see Cotton, Shires & Associates 2001). Corte Madera Creek through Portola Valley seems to be the most important source of human-related bank erosion in the upper watershed. Human-related stream erosion is also significant in Martin and Bull Run Creeks.

Human-related erosion also occurs in Bear Creek and Los Trancos subwatershed, as a result of clearing of riparian vegetation, modification of stream banks, and development along stream banks or in the floodplain. However, the human contribution to erosion is much less than in Corte Madera because of the relatively low rates of bank erosion where development is concentrated, such as through Woodside and along the San Andreas Fault Zone.

Channel Incision
Incision also occurs throughout the San Francisquito Watershed. As discussed in the following section, incision results from reduced sediment supply in some stream reaches.

In other cases, incision may be part of a process of long-term channel adjustment to both natural and human-related changes in the watershed. The extent of incision is generally indicated by "knickpoints" along stream channels, which often become fixed at stream crossings or other instream structures by protective works such as concrete aprons. Failure or removal of the protective works ultimately allows incision to proceed upstream.

Smith and Harden (2002) describe some knickpoints at structures in the Bear watershed, which often create difficult fish passage. Knickpoints or recent incision have also been observed on Bear Creek at Olive Drive, Martin Creek near old La Honda Road and on Bull Run Creek during field investigations. Without surveys, it is difficult to determine when incision began, what caused the incision, and what the typical annual sediment contribution from bed lowering has been. Annual contributions are not thought to be large and the main concerns may be fish passage and habitat modification and deposition at downstream structures, rather than erosion and sediment contributions to streams.

Impaired fish passage created by incision is difficult to treat. If fixed at bridge structures, removal of the aprons or other protective structures may result in damage or failure of the bridge and lead to upstream channel incision and bank erosion, where it may damage private property.

Sediment Trapping or Removal
Trapping of the coarse sediment load that was previously delivered from Corte Madera Creek and other tributaries to San Francisquito Creek in the reservoir behind Searsville Dam is an important component of the incision and bank erosion observed there over the past 100 years. Overall volumes contributed by incision are not large, but lowering of the streambed and steepening of stream banks is thought to be important in accelerating bank erosion rates. Lowering of the streambed of San Francisquito Creek has also resulted in a cycle of incision in the lower reaches of its major tributaries that is particularly obvious along lower Los Trancos Creek.

Bear Gulch is apparently affected by trapping and removal of coarse sediment at the California Water Service (CalWater) diversion weir (Smith and Harden 2002). The extent of downstream incision and bank erosion on Bear Creek has not been documented as it has been on San Francisquito Creek by surveys or other measurements. However, very rough estimates of incision rates suggest that this may be one of the most important sources of human-related erosion along streams in the Bear subwatershed.

SURFACE AND GULLY EROSION

Surface erosion primarily occurs where vegetation is removed and mineral soils are exposed. Human development causes surface erosion at the following sites:

- Construction or development sites
- Agricultural fields
- Roads and trails, including cut and fill slopes, ditches, and gravel-surfaced or native surfaces

- Human-related landslide scars or bank erosion sites
- Human-caused fire damaged sites

Construction or Development
In urban centers such as East Palo Alto, Menlo Park, and Palo Alto, residential areas provided increased sediment delivery during their construction years ago, but they are now mostly built out with stormwater carried to San Francisquito Creek by storm drains. Sediment delivery may now be substantially less than prior to development. In these urban areas, clearing and grading for re-development projects are the greatest potential sources of surface erosion and delivery of sediment to streams. These sources are not thought to be very significant contributors to the human-related sediment yield because of their small area and because of erosion control practices applied to grading and construction.

In rural areas, clearing and grading for new development also potentially provide short-term pulses of sediment that return to average rates when construction is finished and revegetation complete. Again, erosion control practices reduce the significance of construction as a sediment source.

Agricultural Fields
Agricultural fields were not included as a specific source in the Sediment Analysis memorandum. The total area of agricultural land use was estimated to be 490 acres in 1995 (see **nhc** and JSA 2003b), apparently mostly on Stanford Lands in upper San Francisquito Creek. The actual use of this agricultural land and its potential sediment contribution to streams is not known, but agriculture is expected to contribute fine sediment to streams, particularly to San Francisquito Creek.

Roads and Trails
In rural areas, roads and trails are often the major source of surface erosion. Native or gravel-surfaced roads are usually the most significant contributors of sediment; their yields depend on road slope, road and drainage design, road maintenance practices and traffic volumes. Old roads that are incorporated into trail networks in the Santa Cruz Mountains may be important sediment sources. The overview of the road network provided in the Sediment Analysis memorandum indicates that unpaved road and trail erosion was ubiquitous throughout the Santa Cruz Mountains but was particularly significant in upper Corte Madera Creek (San Mateo County and MPROSD), Alambique Creek (Woodside and San Mateo Parks), Bear Gulch and some of the upper tributaries to West Union Creek in Huddart Park. Appendix A provides details on the distribution of unpaved roads and trails by jurisdiction.

It is fairly certain that the estimated erosion rates applied to the roads and trails exaggerate their actual contribution to streams. Field inspection of some trails shows that most are distant from streams, narrow, and well maintained and appear to contribute little sediment to streams; their narrower prism means that they contribute much less sediment per unit length than maintenance or utility roads (see Pacific Watershed Associates

2003). In some parks, maintenance roads are either gravel-surfaced or treated with soil cement (Arastradero Park, Palo Alto) to reduce erosion.

However, specific problem sites remain. These include ditches and cut banks that erode when there are insufficient cross drains, stream crossings with inadequate culverts that block or fail during floods resulting in erosion of the road or trail prism, and severe erosion of the road surface. Such features have been observed in Martin Creek near Old La Honda Road and in Huddart County Park. There are relatively few stream crossings in the Santa Cruz Mountains (see **nhc** and J&S 2003b) but failures may still occasionally contribute significant quantities of sediment (Pacific Watershed Associates 2003).

Landslides and Fire Scars

Erosion of human-related landslide scars and bank erosion provides a small but consistent volume of sediment to streams each year. Vegetative treatments immediately after failure might reduce the yield from these sources. Fire scars are a very important potential source of surface erosion but none were identified in the land use analysis and they are not explicitly included in the sediment analysis.

Gully Erosion

Human-related gully erosion primarily occurs in existing swales or zero order channels rather than from rilling and gully development on previously unaffected slopes. Diversion of local drainage or surface flows from roads, re-development of rural lots with larger homes, or creation of impermeable areas seem to be the main causes of erosion. The erosion caused by incision and bank erosion in gullies or zero-order channels often provides sediment to streams long after direct impacts from development (clearing and grading) are recovered.

The number or length of gullies disturbed by flow diversion from roads or other developments is not well known and has not been mapped or identified in detail. However, field inspections showed such features in Woodside, Portola Valley and Los Trancos Woods and they may occur on moderately steep developed lands throughout the watershed.

3. EXISTING POLICIES AND PRACTICES

The first section of this Chapter summarizes previous reviews of policies and practices for San Mateo and Santa Clara Counties and the towns and cities in the San Francisquito Watershed. The second section discusses some practices that are not included in these reviews, either because they have been developed or adopted since the reviews where completed or because that particular jurisdiction was not included in the reviews.

3.1. Reviews of Policies and Practices

FISHNET 4C REVIEW

Harris *et al* (2001) completed a detailed assessment of existing management practices in Central California Coast Counties for the Fishnet 4C Program. The basic goal of their study was to evaluate the effectiveness of policies and practices on minimizing damage to salmon and their habitat from county funded or regulated activities and to recommend improvements to policies and practices. It did not focus exclusively on erosion or stream management. San Mateo County is the only one of the Central California Coast counties that has jurisdiction in San Francisquito Creek.

In summary, Harris *et al* (2001) found that County plans usually included habitat conservation as a goal but that protective policies were often lacking. San Mateo County lacked a riparian buffer policy or floodplain setback requirement, both of which are considered key policies and regulations for stream protection. However, the County does have sensitive habitat regulations. Harris *et al* (2001) also found that grading controls and erosion control plans were in place for private projects in San Mateo County and that permits were required for construction of stream bank protection structures. However, they noted that implementation and effectiveness of erosion controls was uneven, particularly during the rainy season. One particular lack identified in the report was policies or standards for rural road and culvert maintenance.

Important sediment sources identified by the study were the recurrence of road failures and landslides at certain locations, erosion of stored landslide debris, road spoils, and other materials, and subsequent transport to streams. Sheetwash erosion from unpaved roads and trails and ditch erosion on paved roads were also considered important sediment sources that were not treated or considered directly in policies.

The study also identified specific practices detrimental to salmonids and their habitat. Channel maintenance, particularly clearing of woody debris and vegetation was an important habitat concern. Stream crossings, including culvert replacements and repairs on streams with anadromous salmonid habitat, were significant concerns as were bank stabilization structures, particularly the cumulative impacts from continued local construction along unstable reaches where houses are close to the top of bank.

REGIONAL WATER QUALITY CONTROL BOARD (RWQCB)

The RWQCB (2002) provides a summary of non-point source management measures that were either in place or under consideration in the cities of East Palo Alto, Menlo Park, Palo Alto, the towns of Woodside and Portola Valley, and San Mateo and Santa Clara Counties in August 2001. Their summary is based on inventories prepared by the Santa Clara Valley Urban Runoff Pollution Prevention Program (SCVURPPP) and the San Mateo County Storm Water Prevention Program (SM-STOPPP).

The RWQCB report also notes that sediment management measures are underway by the Joint Powers Authority on San Francisquito Creek. Here, the JPA is implementing the Bank Stabilization and Revegetation Master Plan developed by the cities of Menlo Park, Palo Alto, East Palo Alto and San Mateo and Santa Clara Counties and also coordinates an annual inspection of the creek as part of assessing vegetation removal plans and examining erosion at storm drains.

Table 3-1 summarizes the management measures that were identified during the inventories and indicates which jurisdictions have implemented these measures. Some measures are implemented as part of County-wide NPDES permits.

Table 3-1: Sediment Management Measures Implemented by Jurisdictions in San Francisquito Creek Watershed by 2001

Management Measure	**Jurisdiction**						
	EPA	*MP*	*PA*	*Wood*	*PV*	*SM*	*SC*
Creek Setback Ordinance	●		●	●			
Heritage Tree Ordinance			●	●	●	●	●
Non-Stormwater Ordinance			●	●		●	●
Grading Standards	●	●	●	●	●	●	●
Design Standards	●		●	●	●	●	●
Road Maintenance Standards	●		●		●	●	●
Impervious Surface Limits				●			
BMP Inspections		●	●				
Conservation Easements				●			●
Confined Animal Ordinance						●	

1. EPA is East Palo Alto, MP is Menlo Park, PA is Palo Alto, Wood is Woodside, PV is Portola Valley, SM is San Mateo County, SC is Santa Clara County.

The above measures primarily address sediment management for new development and not management of sediment from existing development. Table 3-1 indicates that grading standards for new development are broadly implemented throughout San Francisquito watershed, as are road maintenance standards and non-stormwater discharge ordinances through countywide NPDES permits. Creek setback ordinances and impervious surface limits are less common.

The table also does not include the land development policies based on managing geologic hazards and flood risk that are implemented for new development in Portola Valley, Woodside, and San Mateo County. Also, this assessment does not include a summary of the policies and practices of all major land managers in the San Francisquito Creek watershed as it does not include the Mid Peninsula Regional Open Space District and some other organizations.

SANTA CLARA MUNICIPAL DEVELOPMENT POLICIES COMPARISON

SCVURPPP (2003b) provided a comparison of development policies, implementing ordinances, regulations and guidelines for their co-permittees. The overall purpose of the project was to develop "model" municipal planning principles and then compare existing policies and practices to the model principles to identify areas for improvement. Regulatory bodies examined in the document that operate in San Francisquito Creek watershed are Santa Clara County, Santa Clara Valley Water District, Palo Alto, and Menlo Park. Recommendations were not prepared for Menlo Park because it is not a co-permittee. The report provides a very detailed summary for each jurisdiction.

The report notes that Palo Alto has a comprehensive set of policies and ordinances and that water quality issues are addressed through the Comprehensive Plan and guidance or standards documents. These documents address water quality and stormwater management by recommending suitable design techniques. SCVURPPP (2002a) also provides a brief description of the sediment management practices of Palo Alto, which focus on construction site stormwater pollution prevention programs. The report notes that San Mateo is nearly entirely built out. San Mateo has adopted the Model Development Policies of SM-STOPPP that address water quality and maintaining stream buffers and native vegetation.

The Santa Clara Valley Water District (SCVWD) is charged with maintaining water quality and managing flood and stormwater on creeks in Santa Clara County. Policies and practices are discussed in the following section.

The report identified six general areas where policies or practices are deficient and where improvements would be beneficial. These were:

- *Erosion and Sediment Control*: Training of municipal engineers and inspectors, design engineers and contractors in design, installation and maintenance of sediment controls.
- *Limiting Site Imperviousness and Incorporating Post-Construction BMPs*: Most municipalities lacked ordinances or regulations to limit or reduce site imperviousness and instead rely on municipal planners or engineers.
- *Requirements for Drainage Design*: Drainage design is addressed by policies and regulations but stormwater treatment and limitations on peak flow and volumes are not included.
- *Natural Resource Protection or Restoration*: Policies, implementation and enforcement of buffers or establishing allowable uses within buffers or for vegetation maintenance vary widely. Recommendations for specific practices are required for many jurisdictions.
- *Promoting Regional or Watershed based Planning and Zoning:* Most agencies lacked policies that allowed preparation of a joint watershed or subwatershed based plan.

3.2. Other Policies or Practices

SAN MATEO COUNTY

In 2001, The County of San Mateo summarized their San Francisquito Creek Watershed Erosion Control and Prevention Plan (San Mateo 2001a). Harris *et al* (2001) reviewed most of the practices summarized in the plan. The San Mateo County Department of Public Works (2001b) has prepared general policies and procedures and provides recommended best management practices (BMP) for their maintenance activities. General guidelines and standards are provided for bank stabilization, slide debris, berms, and large woody debris management or removal, both for emergency and non-emergency maintenance and repair.

San Mateo County Parks and Recreation has begun to assess sediment production from their roads and trails. Their initial assessment focused on Pescadero Creek Watershed (Pacific Watershed Associates 2003). They recognize that roads and trails in Huddart and Wunderlich parks in San Francisquito Creek Watershed are potential sediment sources and are attempting to secure funding for assessment and implementation of erosion control measures.

SCVURPPP RURAL PUBLIC WORKS

SCVURPPP (2003a) and Santa Clara County have also prepared a Performance Standard for their Rural Public Works Maintenance and Support Activities document. The document provides policy statements, an implementation procedure and model BMPs for removal of large woody debris, streambank stabilization, road construction, maintenance and repairs for erosion control, as well as road planning and design BMPs. SCVURPPP also provides performance standards for planning procedures for control of pollutants related to development or redevelopment projects. The County also manages a grading ordinance that provides best management practices for erosion prevention and sediment control (SCVURPPP 2002).

SCVURPPP HYDROMODIFICATION MANAGEMENT PROGRAM

As part of the NPDES permit requirements, Geosyntec Consultants have developed a Hydromodification Management Program (HMP) for the SCVURPPP. The HMP is intended provide management of runoff from new development and significant redevelopment to protect streams, as required under the NPDES permit. To date, a literature review has been completed, an assessment method developed (Geosyntec 2002a & 2002b) and the program has been applied to the Lower Silver-Thompson Creek subwatershed (Geosyntec 2003).

Application of the HMP requires continuous hydrologic simulation and detailed analysis of stream hydraulics, based on cross section surveys and geomorphic analysis. Geosyntec (2003) provides details on methods.

SCVWD (SANTA CLARA VALLEY WATER DISTRICT)

The sediment management practices of the Santa Clara Valley Water District (SCVWD) are described in their Stream Maintenance Program and consist of sediment removal, vegetation management and bank protection. The Existing Conditions Report (**nhc** and J&S 2003b) provides further details, as does the Santa Clara Valley Urban Runoff Pollution Prevention Program (SCVURPPP 2002). The District has a Stream Maintenance Program designed to effectively implement their routine maintenance (SCVWD 2001). The District also removes sediment from San Francisquito Creek upstream of Highway 101 to maintain the bridge opening. This sediment removal is not thought to have any consequences for local or downstream stream erosion.

SCVWD participates in the annual inspections of San Francisquito Creek downstream of Los Trancos Creek and are responsible for vegetation and sediment management. They also identify concerns for bank protection works in their right-of-way and maintain a list for priority maintenance. Through their Ordinance 83-2 they are responsible for the fifty-foot riparian buffer, in collaboration with Palo Alto, and for review of construction and drainage plans to ensure flood conveyance and bank protection.

STANFORD UNIVERSITY

Stanford University has "Special Conditions for Stormwater Pollution Prevention (Revision 4)" that apply to construction projects that are available on their water resources website or through Facilities Operation. Their document provides policies and best management practices that are incorporated in the Storm Water Pollution Prevention Plan (SWPPP) for grading and construction. The contractor, Stanford, or the governing City or County inspects installed BMP daily or weekly, depending on weather.

Stanford has also developed a "Recommended Best Management Practices for Management of Animal Waste, Compost and Sediment on Creeks" that is implemented by their agricultural tenants. Their tenants maintain the private roads on Stanford lands following practices outlined in the Handbook for Forest and Ranch Roads (Weaver and Hagans 1994).

PALO ALTO OPEN SPACES

Palo Alto's Open Space Group manages their Baylands and Arastradero Preserves and Foothills Park. Old roads in Arastradero Park have been closed and revegetated; existing utility roads have been re-surfaced with soil cement to reduce erosion. Foothills Park primarily has dirt paths constructed for recreation and openings constructed for firebreaks. An annual program identifies maintenance concerns and rehabilitates or closes trails and roads that appear to be eroding (Greg Betts; personal communication). We have not reviewed any documents that describe their policies or practices.

MID PENINSULA REGIONAL OPEN SPACE DISTRICT

The policies of the MPROSD are described in their Resource Management Five-Year Strategic Plan (MPROSD 2003). Their overall polices are to protect natural ecosystems and restore disturbed or degraded sites. Their specific practices as applied to roads and trails in their jurisdiction are not known.

GEOLOGICAL HAZARDS (PORTOLA VALLEY, WOODSIDE, SAN MATEO COUNTY)

In the mid-1970s, geologic maps and interpreted movement potential or hazards maps were prepared for the three jurisdictions that manage development on the eastern slopes of the Santa Cruz Mountains. Portola Valley and Woodside have incorporated these maps in their development policies and municipal codes. These maps are used as screening for assessing geological hazards and for identifying sites where site-specific geotechnical or geological investigations are required prior to development.

PORTOLA VALLEY CREEKSIDE CORRIDOR

As part of Portola Valley's initiatives related to erosion control on Corte Madera Creek, Cotton, Shires & Associates (2001) updated their 1984 inventory of bank erosion and bank protection structures through the town. Spangle Associates (2001) also recommended specific regulations for creek protection – these are presently under consideration by the Town Council. As a follow-up to these two studies, Portola Valley and the JPA have contracted for a "Bank Stabilization and Revegetation Recommendations Report" to guide future bank protection works.

SAN FRANCISQUITO CREEK JOINT POWERS AUTHORITY (JPA)

In 2000, the Cities of Menlo Park, Palo Alto, East Palo Alto, the Santa Clara Valley Water District, and the County of San Mateo co-sponsored the San Francisquito Creek Master Plan to provide guidance for future bank stabilization and revegetation projects (RHAA 2000). Subsequently, the Joint Powers Authority (JPA) was charged with management of San Francisquito Creek and the development of demonstration projects, based on the Master Plan. As part of this obligation, they conduct annual creek walks to inspect vegetation growth in the channel and bank erosion.

A contract is underway to develop concept designs for future bank stabilization and revegetation projects at selected sites on San Francisquito Creek between Junipero Serra Boulevard and US Highway 101. This project will describe the selection of suitable demonstration sites, the development of design concepts and the permitting process for implementing the projects.

4. REVIEW AND RECOMMENDATIONS

The following sections discuss information needs and recommend management measures for human-related sediment sources in the San Francisquito Watershed. The Chapter is divided by the major erosion process groups and addresses modification of existing developments to reduce their sediment contributions as well as management of new development. Measures to reduce sediment contributions from natural processes in the watershed are not specifically addressed here.

Table 4-1 summarizes the recommended measures for sediment management for new and existing development that are discussed below.

4.1. Slope Failures

OVERVIEW

In a broad sense, the least stable geologic formations and the greatest risk of accelerated landsliding from development lie in the Santa Cruz Mountains west of the San Andreas Fault Zone, although historic and recent slope failures have also occurred in the Bay Foothills just east of the fault zone (see **nhc** and JSA 2003a). Typically, land use planning for new developments either avoids these landslide hazards by identifying and mapping potentially unstable areas or mitigates them through detailed geologic and geotechnical studies for developments.

Landslides are episodic and occur infrequently, during major storms or earthquakes. Fire or other landscape-level disturbances may greatly accelerate the frequency of landsliding during these storms or earthquakes.

INFORMATION GAPS OR DATA NEEDS

The USGS inspects landslides and slope failures following major storms in the Bay area, focusing on those that damage property. San Mateo and Santa Clara Counties record failures along roads and on public property and often prepare engineering plans to restore landslide damage. Other failures that do not directly damage property are usually not inventoried or described.

At present, there is no organization that maintains a record or database of recent landslides and debris slides and flows in the San Francisquito Watershed, estimates the volumes of sediment delivered to streams, or identifies their causes. Such a database would be helpful in developing a detailed understanding of the factors that control slope failures and of the effect of development on these failures.

The role of large storms in initiation of landslides in the Santa Cruz Mountains is reasonably well understood from studies of landsliding following storms by the USGS. The role of fire in slope stability in the Santa Cruz Mountains is not well understood but, based on studies elsewhere, is likely to greatly accelerate landsliding and sediment supply to streams.

We did not find any documents that describe a coordinated emergency planning to address landslides. Such planning might include removal of debris from streams, revegetation or treatment of landslide scars, diversion of flow from deep-seated landslides, or treatment of fire scars to reduce future erosion and sediment contributions to streams.

MANAGEMENT OF NEW DEVELOPMENT

The towns of Woodside and Portola Valley and the County of San Mateo base their development approvals on maps of geologic hazards prepared in the mid-1970s, policies and ordinances based on these maps, and site-specific geologic and geotechnical studies. San Mateo County is responsible for development in the most active sediment producing areas in the San Francisquito watershed in upper Corte Madera Creek (see **nhc** and JSA 2003c). The MPROSD, Palo Alto (Foothills Park), San Mateo County Parks and Recreation, Peninsula Open Space Trust, CalWater, and Golden Gate National Recreational Area also manage areas of potential landslide or debris flow hazards. These jurisdictions are parks or open spaces and new developments are not expected.

It may be advantageous to update the existing geologic and geologic hazard maps to a common standard for all jurisdictions along the eastern edge of the Santa Cruz Mountains. Such an approach is not likely to greatly alter development approvals, which are generally based on site-specific studies, but may be helpful in regional planning or in emergency response to major storms or fires.

MANAGEMENT OF EXISTING DEVELOPMENT

Reports and inspection of recent air photos suggests that existing roads and trails are the main cause of development-related landslides. Landslides appear to result from failure of cut and fill slopes and, potentially, from diversion and concentration of flow onto marginally stable slopes. Recent human-related landslides have been concentrated in a small area in upper Corte Madera and Los Trancos watersheds and occur along the active and inactive sections of Alpine Road, on private roads and driveways, and along trails. Highways 84 and 35 (Skyline Boulevard) may also contribute to failures and drainage diversion. Reduction of sediment contributions from these sources requires the following steps:

- Studies to map potential landslide hazards along public and private roads and trails and identification of significant factors contributing to instability
- Design of road prism, road drainage or other improvements to address potentially unstable sections of roads. De-activation or re-routing may be required for some road sections.
- Treatment of chronic landsliding sources, such as the Alpine Road failure in upper Corte Madera Creek.

San Mateo County, Portola Valley, MPROSD, and Palo Alto are the main jurisdictions that would be required to sponsor such studies.

Table 4-1: Summary of Recommendations for Sediment Management Measures

Issue	***Information Gaps and Data Needs***	***Recommendations for Management of***	
		New Development	***Existing Development***
Landslide Erosion			
Initiation of Landslides and Debris flows	- Centralized database of slope failures in the watershed - Updated maps of potential landslide hazards areas	New development in landslide susceptible areas is managed through site-specific geotechnical studies; updated hazard maps for east slopes of Santa Cruz Mountains may be beneficial	- Studies to identify potential landslide hazards along public and private roads and trails - Repair or decommissioning of sensitive sites - Treatment of chronic sources, such as Alpine Road
Emergency Planning for Major Storms/Fires	- No coordinated emergency planning to minimize sediment impacts	Not applicable	Not applicable
Stream Erosion			
Hydromodification	- Hydrologic models to assess cumulative impacts and manage new development	- Watershed-based coordinated planning for new development - Adopt policies and regulations for management of impervious area in most jurisdictions - Hydromodification Management Plans (SCVURPPP 2003)	- Retrofit stormwater management (detention or retention storage) where cumulative impacts occur?
Bank Erosion	- Centralized database of bank erosion and bank structures - Field inventory of bank erosion and structures in Bear and Los Trancos Watersheds	- Adopt streamside buffer regulations - Review cumulative impacts of development on stream banks as part of permitting	- Adopt Bank Stabilization and Revegetation Programs - Review impacts of encroachments on stream erosion; consider floodplain mitigation - Develop methods to repair or

Issue	***Information Gaps and Data Needs***	***Recommendations for Management of***	
		New Development	***Existing Development***
			prevent erosion at existing crossings
Channel Incision	- Centralized database of "knickpoints" and incised reaches in the watershed	- Review plans for stream crossing to ensure they accommodate potential channel incision and avoid barriers	- Develop methods to repair or prevent erosion and incision at existing crossings - Develop programs to add large woody debris or structure to streams to slow incision or re-build the bed
Sediment Trapping or Removal	- Recommend surveys of Bear Gulch to document channel incision	- SCVWD removes sediment at Highway 101. Removals have no implications for erosion.	- Work with agencies to restore coarse sediment to Bear Gulch - Continued planning for Searsville Dam
Surface Erosion			
Roads and Trails	- Studies to identify priority erosion sites at crossings, ditches and road surfaces. - Prescriptions for repair or rehabilitation consistent with access and recreation	- Develop consistent standards for trails and private roads for the watershed - Develop best management practices for erosion control	- Repair existing erosion concerns on trails and unpaved roads - Repair erosion concerns on paved road prisms crossing the Santa Cruz Mountains
Grading and Construction	- None identified	- Well addressed by existing policies and regulations - Training in sediment management practices for municipal staff and developers	- Not applicable
Gully Erosion	- Extent of problem is not well known. Inventory and inspection to identify sediment contributions and causes	- Adopt policies and regulations for on-site management of stormwater for new developments	- Develop policies for gully rehabilitation or retrofit of stormwater management where gully erosion is significant

4.2. Stream Erosion

OVERVIEW

Stream incision, bank erosion, and streamside landsliding occur throughout the San Francisquito watershed. These processes can be accelerated by urban development that alters hydrology, by modifications of stream banks, by encroachments onto floodplains or into stream channels, by removal of vegetation and woody debris from streams, or trapping or removal of coarse sediment. Particularly significant human-related incision, bank erosion and streamside landsliding appear to occur along Corte Madera, San Francisquito and Bear Creeks.

INFORMATION GAPS OR DATA NEEDS

The extent that stream hydrographs have been modified by urban development in San Francisquito Creek is an important part of managing new and existing development but it is not well understood. Certainly, a continuous hydrologic model for San Francisquito Creek would allow assessment of existing cumulative impacts and help in management of new development, particularly if watershed-based planning is adopted. The hydrologic model can eventually be incorporated in a Hydromodification Management Plan (HMP) if such an approach is adopted for San Francisquito Creek.

Bank erosion inventories have been prepared for much of the Searsville Watershed and bank structure and erosion inventories have been prepared for part of Corte Madera and much of San Francisquito Creek (see Frey 2000; RHAA 2000; Cotton, Shires and Associates 2001). Existing engineering plans document recent erosion protection work along Alpine Road and upper Corte Madera Creek. Bear and Los Trancos have not been examined in detail.

It would be valuable if an organization maintained a central database of stream erosion in the San Francisquito Creek watershed, similar to that discussed for landslides. An inventory of erosion and bank structures in Bear and Los Trancos watersheds would be required, with the highest priority for the Town of Woodside. Inventories in upper tributaries of Bear and Los Trancos Creeks would also be valuable, as they would indicate which are the most significant sources of sediment. A detailed record of knickpoints, indicating reaches that have been incising, would be valuable in projecting future damage to structures and banks.

MANAGEMENT OF NEW DEVELOPMENT

The primary management measures for stream protection from new development are control or management of impervious areas, establishment of buffer zones, and control and management of bank stabilization works. Altered hydrology from urban impervious areas is not thought to be an important contributor to bank instability or stream incision on Bear, Corte Madera or Los Trancos Creeks now, but peak flows in San Francisquito Creek, Westridge Creek, Bull Run and Martin Creeks, and small tributaries in the Bay Foothills appear to have been altered by development.

The town of Woodside seems to be the only jurisdiction with regulations to manage impervious area (CRWQCB 2002); however, it is not known how these regulations are implemented. One issue is that many watersheds lie in more than one jurisdiction, making it difficult to manage cumulative hydrologic impacts. Regulations to manage hydromodification seem to be particularly important for Portola Valley and for the urban areas that lie along San Francisquito Creek. Again, these regulations would be most effective if a watershed-based planning process is considered.

Few of the jurisdictions in San Francisquito Creek have regulations for streamside buffers although they are being considered in the town of Portola Valley (Spangle Associates 2001) and San Mateo County (CRWQCB 2002) but have not been adopted yet. These regulations are most beneficial where riparian corridors are not already built out.

All the major jurisdictions have a stream permitting process to control construction of bank stabilization work. As noted by Harris *et al* (2001) these permitting regulations generally do not consider cumulative impacts of development and works built during or immediately after flood emergencies often circumvent them (see also Cotton, Shires & Associates 2001). Best management practices for stream bank stabilization that incorporates revegetation and habitat features would be beneficial if adopted by the various jurisdictions, particularly where riparian zones are substantially developed.

MANAGEMENT OF EXISTING DEVELOPMENT

The Bank Stabilization and Revegetation planning process that has been adopted by the Joint Powers Authority for San Francisquito Creek provide a proactive approach that identifies appropriate practices and develops feasible plans for stabilizing eroding banks and upgrading existing protection to incorporate environmental features. Portola Valley is developing a similar process and such an approach is also recommended for Woodside (West Union and Bear Creeks and tributaries) and San Mateo County (Upper Corte Madera Creek).

Floodplain and stream encroachments by roads and stream crossings may contribute to bank erosion and channel incision. Channel erosion along Corte Madera Creek is an important contributor to overall sediment production in this subwatershed and it appears to be aggravated by encroachment of Alpine Road on the stream and its floodplain. Recent upgrades to Alpine Road by Portola Valley document the bank protection structures placed there (see Wilsey Ham 2000). Older engineering plans document past repairs and indicate the general areas of bank erosion and landsliding. Restoration of floodplain would benefit erosion, where this is practical.

Undersized culverts or bridges and other instream structures contribute to channel adjustments. Trapping of bed material upstream of these structures and scour and bed adjustments downstream contribute to overall sediment loads and impair fish passage. Often, knickpoints in the streams are fixed at crossing structures by concrete aprons or other instream works. Failure of bridge protection aprons may initiate stream incision that undermines bank protection structures, leading to their failure and contribution of sediment to downstream reaches (Cotton, Shires & Associates 2001). Private as well as public structures contribute to this problem (see Smith and Harden 2002; Cotton, Shires & Associates 2001).

No jurisdictions seem to have policies or practices for treatment of existing culverts and bridges to restore fish passage while managing or preventing channel incision. While these treatments are likely to be complex and difficult to design and construct, such a program might be valuable for nearly all jurisdictions in the San Francisquito Watershed.

Most jurisdictions have a process for permitting stream crossing structures; and these applications are referred to other agencies for review. However, it is not clear if adequate standards for culverts and bridges have been adopted that address the potential for channel incision beneath these structures. Founding abutments on piles and avoiding instream piers seem to be key design practices for the San Francisquito Watershed. There is a legacy of older, inadequate structures in the San Francisquito Creek watershed that require assessment and upgrading. Counties, towns and cities regularly replace old bridges and culverts and we recommend a review of their design and approval practices to ensure that they provide adequate stream protection.

Similarly, most jurisdictions now have a process for permitting or managing vegetation and large woody debris removal from streams. Santa Clara and San Mateo Counties and their co-permittees have recently adopted best management practices (BMP) for these practices (SCVURPPP 2003; San Mateo 2002b). Past practices may have left many streams lacking in large woody debris and instream vegetation, reducing their ability to resist channel incision. Adding large woody debris may be a suitable restoration process in many streams that will reduce channel incision during large floods and benefit fish habitat. Such programs need to consider local flood levels as part of their design.

Trapping of coarse sediment also affects stream incision and bank erosion. The most significant issue is the trapping of bed material from Corte Madera Creek in Searsville Lake. Planning associated with the filling of Searsville Lake and decommissioning of the Searsville Dam is underway by Stanford University and others. Sediment removals from Bear Gulch at the California Water Service (CalWater) Diversion Dam (see Smith and Harden 2002) are thought to contribute to downstream channel incision on West Union and Bear Creeks; however, it is not clear what the actual practices are at this site. Such removals do not appear to be under the control of Woodside or San Mateo County; however, it would be beneficial if this sediment was placed downstream of the weir rather than removed from the stream. At least, a monitoring program for Bear Gulch is recommended.

4.3. Surface Erosion (Roads and Trails)

OVERVIEW

Roads, particularly rural roads, are important sediment sources in the San Francisquito Creek watershed (see **nhc** and JSA 2003b; 2003c). Erosion occurs on cut and fill slopes, in ditches and from unpaved road surfaces, either gravel-surfaced or native. Road crossings, particularly culverts on trails and native roads, are also potential sediment sources. Culvert blockage, overflow of the road surface, and failure of the road prism can contribute occasional, large quantities of sediment (Pacific Watershed Associates 2003).

INFORMATION GAPS AND DATA NEEDS

The road and trail network is well represented in the GIS of San Francisquito Creek; however, sediment contributions have been estimated from average values applied to the network. Typically, road erosion is concentrated at relatively few sites. Field inspections indicated erosion problems in Huddart County Park, on the closed section of Alpine Road, and along sections of trails in Foothills Park and through the MPROSD.

A detailed assessment and erosion control program seems to be required for all the unpaved roads and trails in the San Francisquito Watershed. While such a program could be undertaken by the individual jurisdictions it might be best if coordinated by a central authority in order to assign adequate priorities for the expenditures of funds. Such a program would include:

- Inventory of stream crossing of roads and trails, identifying existing erosion problems and the adequacy of crossing structures
- Inventory of areas of ditch and road surface erosion that contribute sediment to streams
- Development of prescriptions and costs for rehabilitation of stream crossings and eroding roads consistent with access requirements and recreation use.
- BMPs for road and trail erosion management

Some paved roads in the Santa Cruz Mountains, such as Kings Mountain Road and Highway 84, experience ditch erosion, cut slope slides, and "slip-outs (fill failures)" during major storms. It would be valuable to extend the inventory to include paved roads and develop potential prescriptions for reducing erosion.

San Mateo County's best management practices (County of San Mateo 2001b) include storage of debris from slides and slipouts, preventing erosion of this material or its disposal near streams and a similar practice is incorporated in SCVURPPP (2003).

MANAGEMENT OF NEW DEVELOPMENT

SCVURPPP (2003) provides standards for design, construction and maintenance of rural public roads, both paved and unpaved. These standards have been adopted by all the political jurisdictions in San Francisquito Creek and appear to be adequate to minimize sediment from construction and maintenance. Erosion from native or gravel road surfaces will continue unless the road surfaces are sealed or paved.

Private roads and driveways and trails – including trails that occupy old roads – are not covered by these standards. This includes trails and old roads in San Mateo County Parks (Huddart and Wunderlich), Palo Alto (Foothills Park and Arastradero Preserve) and in the Midpeninsula Regional Open Space District (Los Trancos, Coal Creek, Windy Hill, Thornewood and Teague Hill) and Stanford University (Jasper Ridge Preserve). Based on limited discussions and field inspections, construction and maintenance practices differ considerably from one jurisdiction to another and it would be beneficial to adopt uniform trail standards or best management practices that could be applied across the watershed.

MANAGEMENT OF EXISTING DEVELOPMENT

The steps in managing sediment contributions from existing trails and roads are described under "Information Gaps and Data Needs".

4.4. Surface Erosion (Grading and Construction)

OVERVIEW AND INFORMATION GAPS

Grading for new construction typically exposes mineral soil that may be eroded during storms. The actual quantities delivered to streams from this process are thought to be very small, primarily because of the policies and best management practices already adopted by the jurisdictions in San Francisquito Creek. We see no need for studies to better evaluate actual sediment contributions from this process.

MANAGEMENT OF NEW DEVELOPMENT

All the jurisdictions in San Francisquito Creek have policies and regulations that manage grading for new construction. Palo Alto also provides guidelines for suitable design techniques for water quality and stormwater management that might be adopted elsewhere. The primary issue or concern noted in previous reviews has been uneven enforcement and maintenance of erosion controls. SCVURPPP (2003) recommends training programs for municipal engineers and inspectors and design engineers and contractors in sediment management practices.

4.5. Gully Erosion

OVERVIEW

Human-related gully erosion primarily occurs from incision or bank erosion in existing swales or zero order channels rather than from rilling and gully development on previously unaffected lands. Diversion of local drainage or surface flows from roads, development of rural lots with large homes, and creation of impermeable areas seem to be the main sources of increased flows that cause erosion. The erosion caused by incision and bank erosion in gullies or zero-order channels often provides sediment to streams long after direct surface erosion from development (clearing and grading) has recovered.

INFORMATION GAPS AND DATA NEEDS

The overall number and length of gullies in San Francisquito Creek has only been roughly estimated and the gullies disturbed by flow diversion from roads or other developments have neither been measured nor mapped. However, field inspections identified eroding gullies in Woodside, Portola Valley and Los Trancos Woods and they may be fairly widespread in the watershed. Further inventory and inspection is recommended to identify the potential extent and sediment contribution of human-related gully erosion.

MANAGEMENT OF NEW DEVELOPMENT

In Palo Alto, the provisions of their Grading and Erosion and Sediment Control require management of the quality and quantity of stormwater flows from new development or re-development sites. Zoning regulations that manage the total impervious area that can be developed on a lot also help control stormwater flows. Other rural jurisdictions such as Portola Valley, Woodside, and unincorporated San Mateo County do not seem to have similar policies or practices and we recommend that they be adopted in these jurisdictions.

MANAGEMENT OF EXISTING DEVELOPMENT

No jurisdictions seem to have policies for rehabilitating or restoring eroding gullies or zero order stream channels, although some repairs may be undertaken as part of public works maintenance. Various best management practices are available to reduce erosion in the gullies, ranging from in-gully bed and bank stabilization to retrofitting stormwater management BMPs.

5. SUMMARY AND CONCLUSIONS

San Francisquito Watershed lies partly in Santa Clara but mostly in San Mateo County. The cities and towns with jurisdiction over land development are East Palo Alto, Palo Alto, Menlo Park, Woodside and Portola Valley. Much of the upper watershed lies in the Mid Peninsula Regional Open Space District, San Mateo County Parks, Palo Alto Open Spaces or other preserves, parks or recreation areas. Stanford University is the largest private landowner in the watershed. The large number of jurisdictions makes sediment management difficult in the San Francisquito Creek watershed.

The Santa Clara Valley Urban Runoff Pollution Prevention Program (SCVURPPP) and San Mateo Countywide Stormwater Pollution Prevention Program (SM-STOPPP) administer the National Pollution Discharge Elimination System (NPDES) permits for the two counties. Both organizations are very involved in reviewing existing water quality management policies and regulations in the watershed and active in developing and promoting policies, regulations and best management practices.

Most of the reviews of existing policies and regulations and recommendations for improvements focus on managing new private and public development, particularly on grading and erosion and sediment control. While new development can be a component of the human-related sediment contribution to streams, existing development is usually more significant. Few policies and regulations address rehabilitation of existing development to reduce sediment impacts.

Our review focused on management of human-related erosion from landslides, streams and surface processes, both for new and for existing development. One important issue that arose from the review was a need for an overall planning or coordinating agency for sediment management in the San Francisquito Watershed. Such an agency would coordinate the different jurisdictions and help develop common standards. The agency would develop watershed-wide inventories or databases of landslides, and stream, road, and gully erosion and organize field inspections to complete databases. It would also develop and coordinate emergency planning for sediment management following storms or fires, and coordinate watershed-based planning and assessment studies for development.

The main improvements for sediment management focus on managing stream erosion and rehabilitating roads and trails. The existing hydrology of the watershed, and human impacts on peak flows, are not well understood but they likely to contribute to stream erosion in San Francisquito Creek and in some sub-subwatersheds in the upper basin. A key step is to develop a hydrologic model of the watershed that allows assessment of cumulative impacts from existing development and management of potential impacts of future development.

Bank erosion and channel incision are also affected by human modifications of stream banks, stream crossing structures and encroachments on floodplains and streams.

Adoption of streamside buffer regulations would benefit bank erosion where riparian areas are not developed; however, many riparian areas are already developed and the buffers will provide limited benefit there. Instead, bank stabilization and revegetation programs that provide standards to reduce erosion and restore habitat features seem to be the most beneficial approach. Such programs also will help reduce the number of poorly designed and constructed emergency bank protection works.

Bridges and culverts are important components of stream erosion. Channel incision is often stopped at bridges by aprons or other instream works, which often results in fish passage barriers. Careful review of proposed crossings to ensure that they can accommodate channel incision or other adjustments is a priority, as are programs to address existing barriers. The problem is complex as removal of aprons or other structures may result in failure of the structure and upstream incision, bank erosion and property damage.

Unpaved roads and trails are the major source of surface erosion in the upper watershed and they also contribute to initiation of landslides in susceptible areas. A coordinated study is required to assess existing priority erosion areas and rehabilitate them throughout the Santa Cruz Mountains. Development of common standards for trail construction and erosion control best management practices is also recommended.

Human-related gully erosion also contributes sediment to streams. While not well documented, this erosion appears to result from stormwater from roads and developments that enters swales or zero-order streams. Adoption of policies and regulations for on-site stormwater management is recommended for some rural jurisdictions. Gully rehabilitation or retrofit of stormwater management practices may be required for the most significant erosion sites.

6. REFERENCES

Brown, W. and J. Jackson. 1973. Erosional and deposition provinces and sediment transport in the south and central part of the San Francisco Bay Region, California. USGS Miscellaneous Field Studies MF-515. 21 p. Pamphlet and Maps.

California Regional Water Quality Control Board. 2002 (August). San Francisquito Creek Sediment TMDL: Progress Report. California Environmental Protection Agency, Oakland. 26 p.

Cotton, Shires & Associates, Inc. 2001 (August). Stream Flow Hazards Evaluation – 2001. Lower Corte Madera Creek. Town of Portola Valley, California. 38 p.

Crippen, J.R. and A. Waananen. 1969. Hydrologic Effects of Suburban Development near Palo Alto, California. USGS Open-File Report. January 23. 35 pp.

Cummings, J. and Wm. Spangle & Associates (Compilers). 1975. Geologic Map: Town of Portola Valley, San Mateo County, California. Scale 1:6,000

County of San Mateo. 2001a. Endangered Species and Watershed Protection Program. Volume 1: Maintenance Standards. Department of Public Works.

County of San Mateo. 2001b. San Mateo County Trails Plan. San Mateo County Department of Parks and Recreation.

County of San Mateo. 2001c (September). San Francisquito Creek Watershed Erosion Control and Prevention Plan. 5 p.

Dickinson, W., J. Cummings and Wm. Cotton and Associates. 1992(?). Geologic Map: Town of Woodside, San Mateo County, California. Scale 1:7,200.

Geosyntec Consultants. 2002a. Recommended Assessment Method for Developing the Hydromodification Management Plan, including Data Requirements. Technical Memorandum #1 to Santa Clara Urban Runoff Pollution Prevention Program.

Geosyntec Consultants. 2002b. Hydromodification Management Plan: Literature Review. Santa Clara Urban Runoff Pollution Prevention Program.

Geosyntec Consultants. 2003. Hydromodification Management Plan Draft Interim Report: Assessment of the Lower Silver – Thompson Creek Subwatershed. Santa Clara Urban Runoff Pollution Prevention Program. 91 pp and Appendices.

Harris, R.R., S. Kocher and K.M. Kull. 2001. Effects of County Land Use Policies and Management Practices on Anadromous Salmon and Their Habitats: Sonoma, Marin, San Mateo, Santa Cruz and Monterey Counties, California. FishNet 4C Program. 69 p.

Jayko, A, J. De Mouthe, K. Lajoie, D. Ramsey and J. Godt. 1999. Map showing locations of damaging landslides in San Mateo County, California, resulting from 1997-98 El Nino Rainstorms. USGS Miscellaneous Field Studies Map MF-2325-H.

Knott, J.M. 1973. Effects of Urbanization on Streamflow and Sediment Discharge in the Colma Creek Basin, California. USGS Open-File Report. 54 pp.

Midpeninsula Regional Open Space District. 2003. Resource Management Five-Year Strategic Plan. 18 p.

Northwest Hydraulic Consultants and Jones & Stokes Associates. 2003a. San Francisquito Creek Historic Conditions Analysis. San Francisquito Creek Joint Powers Authority. 35 p and Appendices.

Northwest Hydraulic Consultants and Jones & Stokes Associates. 2003b. San Francisquito Creek Existing Conditions Analysis. San Francisquito Creek Joint Powers Authority. 26 p and Tables and Figures.

Northwest Hydraulic Consultants and Jones & Stokes Associates. 2003c. San Francisquito Creek Watershed Sediment Analysis. San Francisquito Creek Joint Powers Authority. 60 p and Appendices.

Pacific Watershed Associates. 2003. Sediment Assessment of Roads within the Pescadero/Memorial/Sam McDonald County Park Complex, Pescadero Creek Watershed, San Mateo County, California (#39000-02-C212). San Mateo County Parks and Recreation Department and California Department of Fish and Game. 50 p.

Rodine, J.D, C. Price and others. 1975. Geology and movement potential within the Town of Portola Valley, California. Town of Portola Valley.

Royston, Hanamoto, Alley and Abey, Philip Williams & Associates, H.T. Harvey & Associates, Environmental Science Associates and Frederick T. Seher & Associates. 2000. San Francisquito Creek Bank Stabilization and Revegetation: Existing Conditions Report. Prepared for City of Menlo Park, City of Palo Alto, City of East Palo Alto, Santa Clara Valley Water District and County of San Mateo. 121 pp.

Santa Clara Valley Urban Runoff Pollution Prevention Program (SCVURPPP). 2002 (March 1st). San Francisquito Creek Watershed Assessment of Sediment Management Practices: Plan and Schedule. 25 p.

Santa Clara Valley Urban Runoff Pollution Prevention Program (SCVURPPP). 2003a. Fiscal Year 2003-2004 Work Plan. Performance Standards Revisions (Section 2). Performance Standard and Supporting Documents for Rural Public Works Maintenance and Support Activities. 19 p.

Santa Clara Valley Urban Runoff Pollution Prevention Program (SCVURPPP). 2003b. Santa Clara Basin Municipal Development Policies Comparison Project (April). In Association with The Santa Clara Basin Watershed Management Initiative's Land Use Subgroup..

Santa Clara Valley Water District. 2001. Draft Environmental Impact Report and Stream Maintenance Program Report for the Multi-Year Stream Maintenance Program.

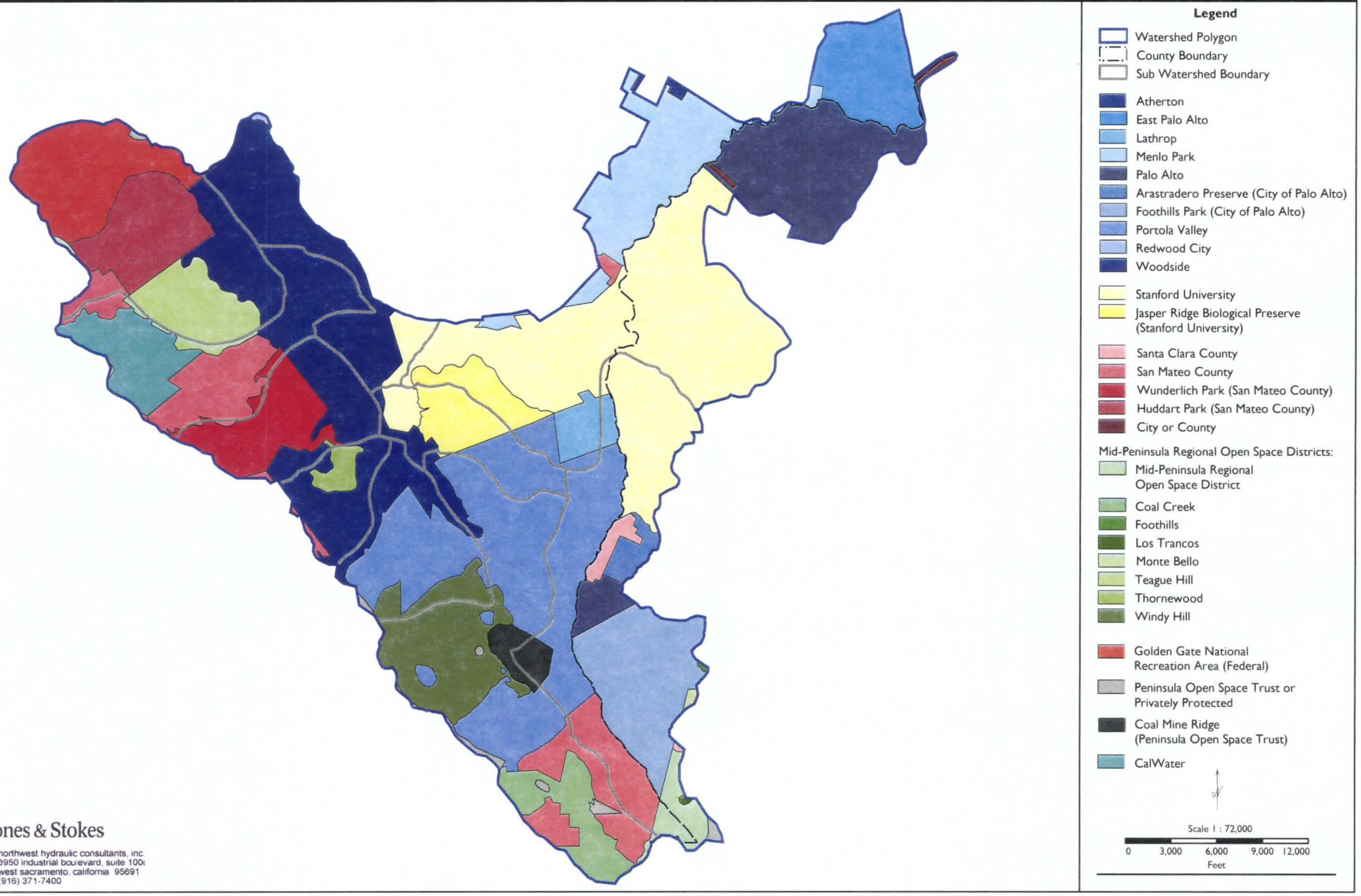
Smith, J.J. and D. Harden. 2001. Adult Steelhead passage in the Bear Creek Watershed. San Francisquito Watershed Council. 65 p.

Spangle Associates. 2001 (June 20th). Creekside Corridor Regulations: Analysis and Recommendations. Town of Portola Valley. 61 p.

Weaver, W and P. Hagans. 1994. Handbook for Forest and Ranch Roads: A guide for planning, designing, constructing, reconstructing, maintaining and closing wildlife roads. Mendocino County Resource Conservation District, Department of Forestry and Fire Protection, and USDA Soil Conservation Service.

Wilsey Ham. 2000. Town of Portola Valley: Alpine Road Permanent Restoration – Phase 2. Federal Aid Project No ER 3639(008). Alpine Road south of Willowbrook Drive. 38 sheets.

Figure 1 San Francisquito Watershed Jurisdiction Map

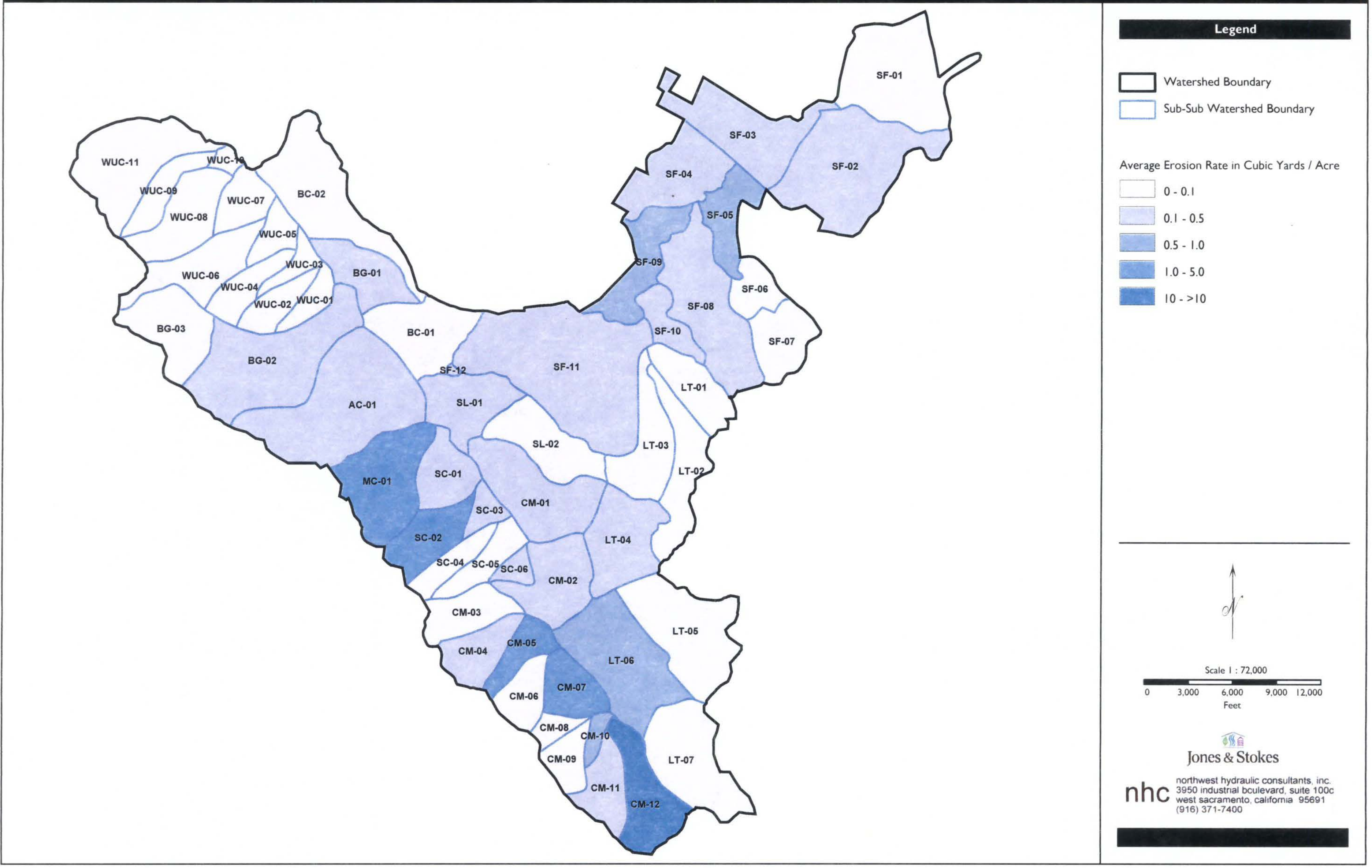

Legend
Watershed Polygon
County Boundary
Sub Watershed Boundary
Atherton
East Palo Alto
Lathrop
Menlo Park
Palo Alto
Arastradero Preserve (City of Palo Alto)
Foothills Park (City of Palo Alto)
Portola Valley
Redwood City
Woodside
Stanford University
Jasper Ridge Biological Preserve (Stanford University)
Santa Clara County
San Mateo County
Wunderlich Park (San Mateo County)
Huddart Park (San Mateo County)
City or County
Mid-Peninsula Regional Open Space Districts:
Mid-Peninsula Regional Open Space District
Coal Creek
Foothills
Los Trancos
Monte Bello
Teague Hill
Thornewood
Windy Hill
Golden Gate National Recreation Area (Federal)
Peninsula Open Space Trust or Privately Protected
Coal Mine Ridge (Peninsula Open Space Trust)
CalWater
N
Scale 1 : 72,000
0
3,000
6,000
9,000
12,000
Feet

Jones & Stokes

nhc
northwest hydraulic consultants, inc.
3950 industrial boulevard, suite 100
west sacramento, california 95691
(916) 371-7400

N:/NHC/03003.03/ARCMAP/SF_JURIS01_17X11.MXD (11/11/03) CN

Figure 2 Human - related Erosion in Sub-subwatersheds in the San Francisquito Watershed



N: / NHC / 03003.03 / ARCMAP / HUMAN_EROSION_17X11.MXD (11.20.03) CN

Figure 3
San Francisquito Creek Watershed
Principal Predicted Debris_Flow Source Areas Per Jurisdiction

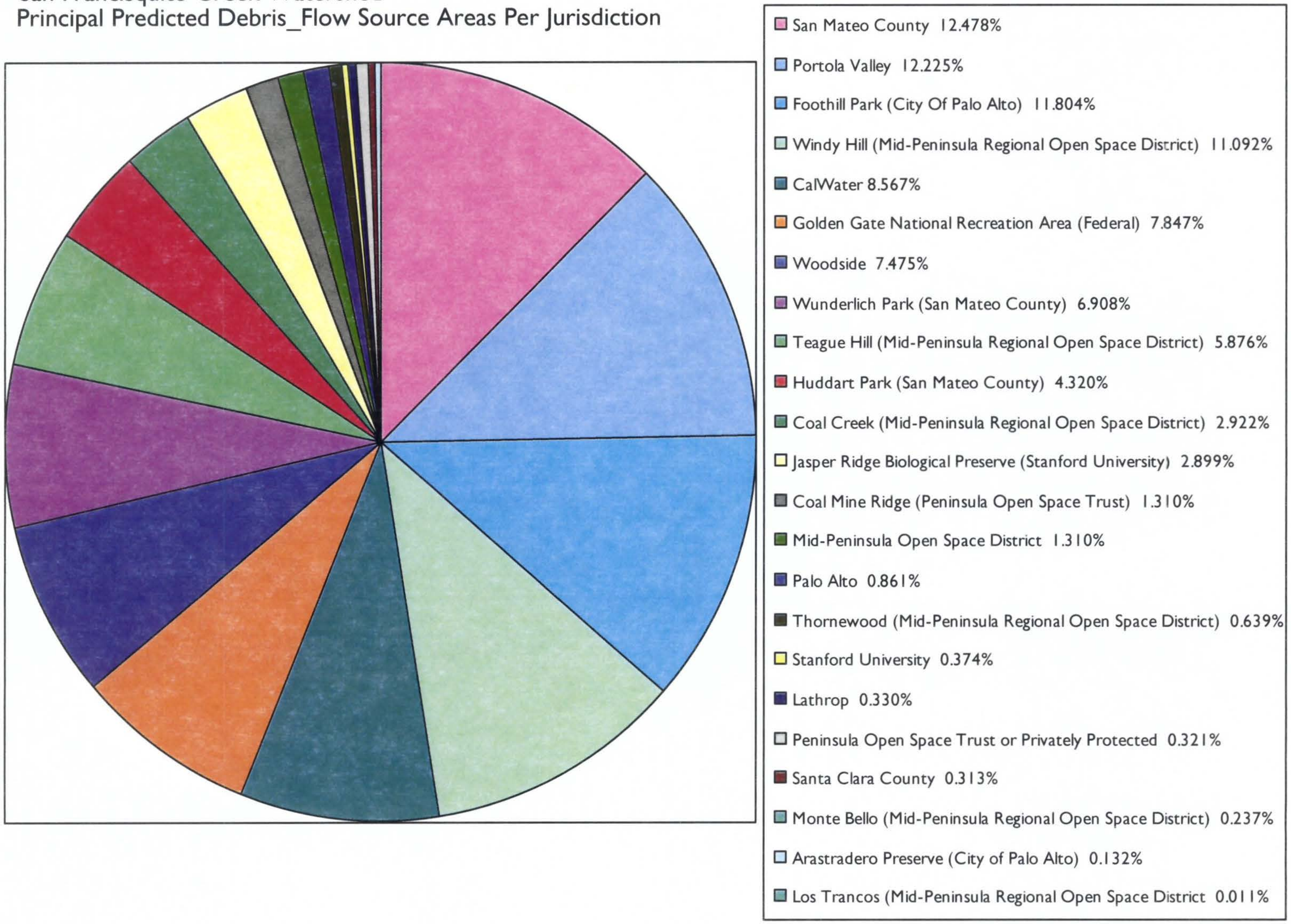


Figure 4
San Francisquito Creek Watershed
Mostly Landslide Areas per Jurisdiction

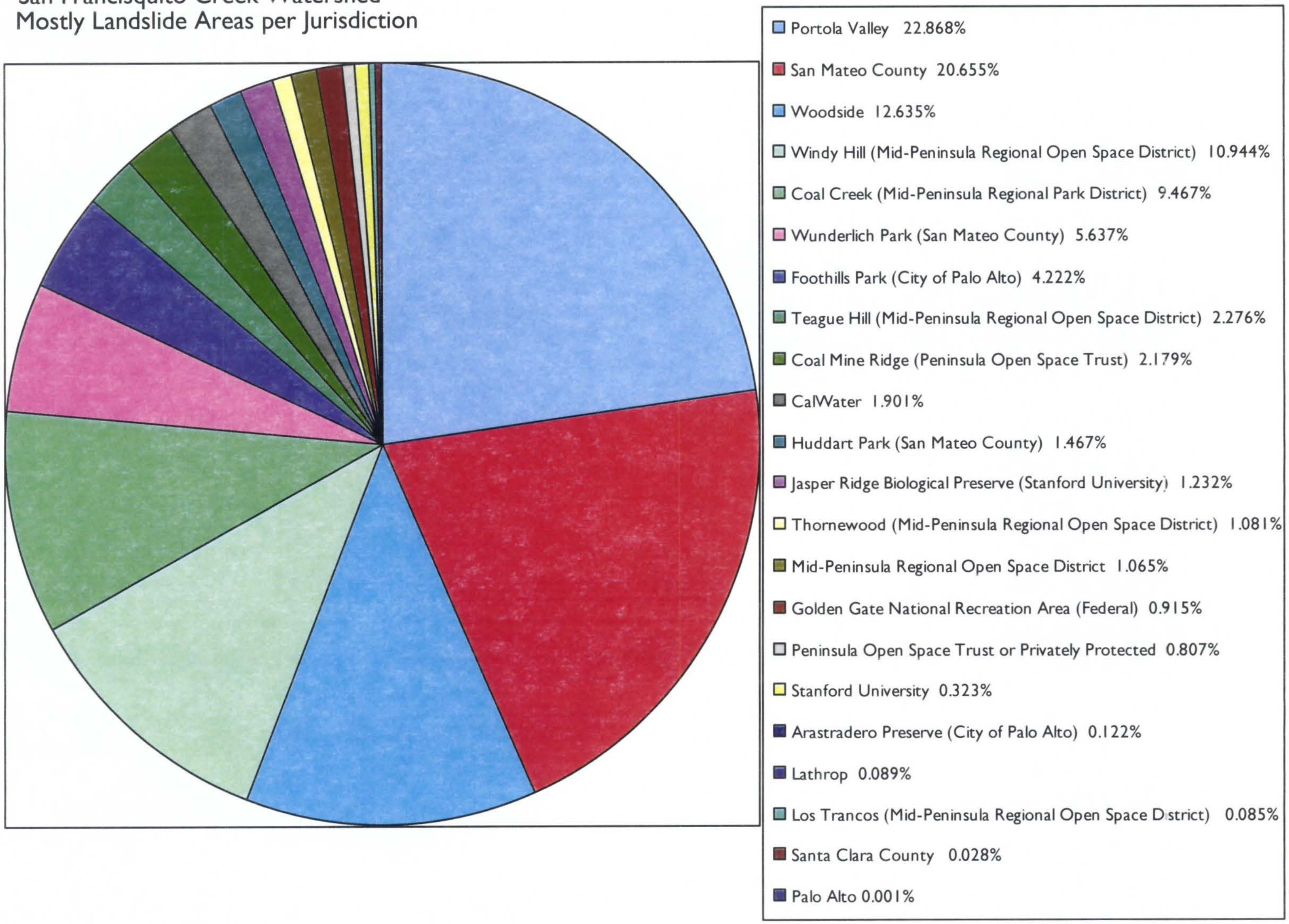


Table A.1 Paved Roads and Unpaved Roads and Trails by Jurisdictions

Jurisdiction	Length of roads (miles)		Length of roads within given slope class (miles)						Length of roads within erosive geologies (miles)	
			0 - 20 degrees		20 - 35 degrees		35+ degrees			
	Paved	Unpaved [1]	paved	unpaved	paved	unpaved	paved	unpaved	paved	unpaved
Arastradero Preserve (Palo Alto)	1.40	0.20	1.10	0.20	0.24	0.01	0.06	0.0	0.52	0
CalWater	0.70	1.99	0.46	0.16	0.16	0.25	0.09	1.57	0.70	1.99
East Palo Alto	27.18	0.09	27.18	0.09	0	0	0	0	0	0
Foothills Park (Palo Alto)	2.57	5.99	1.57	3.42	0.90	1.91	0.11	0.65	0	0
Golden Gate NRA	0.58	1.04	0.58	0.81	0	0.23	0	0	0.58	0.96
Huddart Park (San Mateo)	4.32	6.15	2.12	2.97	1.85	2.31	0.36	0.88	3.88	5.92
Jasper Ridge (Stanford)	0.09	3.34	0.09	2.84	0	0.47	0	0.12	0	0.50
Menlo Park	45.76	0.31	45.76	0.31	0	0	0	0	0.26	0
MPROSD (Coal Creek)	2.76	4.09	0.42	1.11	1.31	2.33	1.02	0.66	2.74	4.09
MPROSD (Foothills)	0.15	0	0.07	0	0.07	0	0	0	0	0
MPROSD (Los Trancos)	0.14	0.07	0.14	0.04	0	0.02	0	0.01	0	0
MPROSD	2.02	0.85	1.21	0.46	0.70	0.20	0.11	0.19	1.20	0.16
MPROSD (Monte Bello)	0.14	0.22	0.02	0	0.10	0.17	0.02	0.05	0	0
MPROSD (Teague Hill)	0.42	0.88	0.24	0.45	0.17	0.43	0.02	0	0.42	0.88
MPROSD (Thornewood)	1.17	0.20	0.46	0.02	0.64	0.10	0.08	0.08	1.17	0.20
MPROSD (Windy Hill)	3.45	6.08	1.26	2.55	1.25	2.45	0.94	1.08	3.03	5.22
Palo Alto (exc Foothills and Arastradero)	64.77	0.89	63.34	0.77	1.29	0.11	0.14	0.04	0	0
Peninsula Open Space Trust (Coal Mine)	0.97	0.94	0.65	0.51	0.29	0.42	0.03	0.0	0.73	0.94
Peninsula Open Space or Privately Protected	1.23	0.18	0.55	0.01	0.55	0.14	0.14	0.04	1.04	0.18
Portola Valley	46.4	11,41	35.95	5.29	9.25	4.47	1.20	1.65	31.23	7.33
San Mateo County (Unincorporated)	14.38	7.74	7.24	2.39	6.23	3.38	0.91	1.97	10.07	6.61
Santa Clara County (Unincorporated)	1.04	0.71	0.84	0.62	0.20	0.09	0	0	0.56	0.14
Stanford University	58.25	16.14	56.79	15.22	1.39	0.87	0.07	0.05	16.12	5.92
Woodside	61.45	10.07	47.27	4.61	11.69	4.72	2.49	0.74	38.43	6.78
Wunderlich Park (San Mateo)	0.08	9.52	0.05	1.87	0.03	4.01	0	3.65	0.08	9.52

[1] "Unpaved" includes both unpaved roads and trails.

Sediment
Reduction Plan

Final Project
Report

Work Plans

1

Cauve

SEDIMENT MANAGEMENT PLAN FOR SAN FRANCISQUITO CREEK (C.9.f.ii.)

Santa Clara Valley Urban Runoff Pollution Prevention Program
FY 2002-2003 Work Plan

SAN FRANCISQUITO CREEK WATERSHED ASSESSMENT OF SEDIMENT MANAGEMENT PRACTICES

PLAN AND SCHEDULE

REVISED

October 15, 2002

SANTA CLARA VALLEY
URBAN RUNOFF POLLUTION PREVENTION PROGRAM

Submitted in fulfillment of
SCVURPPP NPDES Permit Provision 9(f)(ii)

CO-PERMITTEES:

SANTA CLARA VALLEY WATER DISTRICT

COUNTY OF SANTA CLARA

CITY OF PALO ALTO

SAN FRANCISQUITO CREEK WATERSHED
ASSESSMENT OF SEDIMENT MANAGEMENT PRACTICES
PLAN AND SCHEDULE

Introduction

This workplan is submitted in fulfillment of the Santa Clara Valley Urban Runoff Pollution Prevention Program (SCVURPPP) NPDES permit Provision 9(f)(ii) and the San Mateo County-wide Stormwater Pollution Prevention Program (SM-STOPPP) provision C.10. The SCVURPPP and SM-STOPPP permit provision requires the Programs to submit a workplan and schedule to the Regional Board to conduct an assessment of sediment management practices. In this workplan, the key tasks are identified as they relate to assessing the sediment management practices conducted in the watershed. The plan outlines the goal, objectives, and approach that the Programs and its co-permittees will use to assess sediment management practices in the San Francisquito Creek watershed. This effort will also support a holistic approach to watershed management in the development and implementation of the most practicable erosion control and sediment management measures. In addition, this study is anticipated to produce information that will assist the Regional Board in preparing a sediment Total Maximum Daily Load (TMDL) Implementation Plan for the watershed.

Background

The proposed project presented in this work plan will assist the co-permittees of the Santa Clara Valley Urban Runoff Program (SCVURPPP) and the San Mateo Countywide Stormwater Pollution Prevention Program (SM-STOPPP) to comply with the management of sediment impairment and control provision in their respective storm water NPDES permits. The co-permittees of the SCVURPPP include the Santa Clara Valley Water District, County of Santa Clara, and the City of Palo Alto. The co-permittees of the SM-STOPPP include the County of San Mateo, the City of East Palo Alto, the City of Menlo Park, the Town of Woodside, and the Town of Portola Valley.

Provision 9(f)(ii) of the Santa Clara Valley Urban Runoff Pollution Prevention Program NPDES Permit Order No. 01-024 reads as follows:

> "**San Francisquito Creek.** Submit a plan and time schedule for implementation acceptable to the Executive Officer by March 1, 2002 to conduct, in cooperation with STOPPP, an assessment of management practices that are currently being implemented and additional management practices that will be implemented to prevent or reduce excess sediment impairment in urban creeks, and implement any additional management practices necessary to prevent or reduce excess sediment impairment in San Francisquito Creeks. Such management practices may include but are not limited to: management and/or removal of large woody debris and live vegetation from channels; streambank stabilization projects; road construction, operation, maintenance, and repairs to prevent and control

> road-related erosion; management of construction related sediment; and management of post-construction sediment from areas of new development or redevelopment."

Provision C.10 of the reissued San Mateo Countywide Stormwater Pollution Prevention Program NPDES Permit Order 99-059 reads as follows:

> "**Watershed Management Initiative for San Francisquito Creek:** East Palo Alto, Menlo Park, Woodside, Portola Valley, and the County of San Mateo ("Municipalities") shall develop and implement an erosion control and prevention plan and diazinon toxicity reduction plan. A draft scope of work and outline for the report(s) shall be submitted by September 1, 2000. Interim draft report(s) shall be submitted by March 1, 2001, and final report(s) shall be submitted by September 1, 2001. The final report(s) shall include a schedule for implementation of the plan(s). In addition to, and to facilitate the development of the reports specified above, the dischargers shall coordinate with and participate in the development of the watershed assessment and management plan for San Francisquito Creek watershed and the Santa Clara basin that is being developed through the Santa Clara Basin Watershed Management Initiative.

The final scope of the SM-STOPPP Erosion Control and Prevention Plan was submitted to the Regional Board by San Mateo County on behalf of the SM-STOPPP co-permittees (San Mateo County, East Palo Alto, Menlo Park, Woodside, Portola Valley) on September 1, 2001.

The co-permittees for the SCVURPPP and SM-STOPPP, along with other agencies and organizations in the watershed, are actively participating in a stakeholder process and are working in cooperation and coordination in development of a holistic, watershed approach to sediment assessment and analysis to determine sediment loadings and impacts in the watershed, and the characterization of management practices to reduce sediment impairments. As directed by the Regional Board, SCVURPPP and SM-STOPPP have planned in coordination a sediment assessment of the watershed including problem identification, defining goals and objectives, and the coordination of ongoing efforts within the watershed. The proposed sediment assessment provides a comprehensive study of sedimentation issues impacting the watershed that will utilize sediment analyses currently being pursued in the watershed by the U.S. Geological Survey and Stanford University.

The basic components of a watershed sediment assessment and analysis include a problem statement, quantitative characterization of sediment and hydrologic inputs, source identification, sediment loadings analysis and land use contributions, sediment transport, characterize channel and habitat condition, and potential management options. The watershed sediment assessment and analysis will require an integrated approach involving all of the jurisdictions, resource agencies and the community who have an interest in its outcome. A stakeholder work group has been formed to address the watershed assessments, and is comprised of representatives from the County of San Mateo, County of Santa Clara, USGS, Stanford University, Santa Clara Valley Water

District, San Mateo County Stormwater Pollution Prevention Program (SM-STOPPP), Santa Clara Valley Urban Runoff Pollution Prevention Program (SCVURPPP), San Francisquito JPA, and the San Francisquito Watershed Council (formerly CRMP).

In addition, the stakeholders were successful in the award of a Proposition 13 Phase I grant (Prop 13 Grant Project) for watershed sediment analysis and development of a sediment reduction plan, titled the *San Francisquito Creek Watershed Analysis and Sediment Reduction Plan* project. The Prop 13 Grant Project Task 7 funds development of a sediment reduction plan based on an assessment of existing management practices, and evaluation and recommendations for additional erosion control measures to be implemented. A large portion of the work for this plan is contingent on the Prop 13 Grant Project scope developed by the grant Technical Advisory Committee. Therefore, the plan implementation and schedule as presented in the March 2002 submittal is revised in this version to align with the scope and schedule for the Sediment Reduction Plan developed under the Prop 13 Grant Project Task 7. The stakeholders will conduct the sediment assessment, and develop and implement a control measures plan in the holistic context of watershed management and in coordination of the Santa Clara Basin Watershed Management Initiative.

Due to delays in the Prop 13 Grant contract process at the State Water Resources Control Board (SWRCB), the grant project is more than 12 months behind schedule as planned. The consultant selection was completed September 2002, however, at the time of this revision, the contract process has still not been finalized at the State office. At this time, the grant money is not expected to be available until after January 2003. In order to prevent further delays, the RWQCB has requested an early start date from the SWRCB, and depending on availability of funds and services from stakeholders, the grant project is anticipated to commence mid-October 2002. The schedule presented in this revision, is based on the scope and schedule negotiated between the TAC and the project consultant as of October 2002, and assuming approval of an early start date prior to contract award.

A brief listing of current and planned sediment management practices by the SCVURPPP co-permittees (Santa Clara Valley Water District, Palo Alto, County of Santa Clara) is presented in Table 2. Attachment A – C also provides a brief description of the co-permittees sediment management activities for the SCVWD, Palo Alto, and County of Santa Clara, respectively. Attachment D summarizes the current and planned erosion control and prevention measures of the SM-STOPPP co-permittees (County of San Mateo, East Palo Alto, Menlo Park, Woodside, Portola Valley). In addition to practices by the co-permittees of the two programs, the plan will also survey management practices of jurisdictions, agencies and large landowners within the watershed, such as Mid-Peninsula Regional Open Space District (MROSD), Golden Gate National Recreation Area (GGNRA), and California Department of Transportation (Caltrans). This effort will also review ongoing and proposed efforts by the SCVURPPP, the WMI, and the San Francisquito Watershed Council to compare and contrast agency planning, permitting and model development principles.

As the sediment assessment project and assessment of management measures moves forward, the co-permittees will continue to proceed with on-going or planned sediment management practices that are presented in Table 2. During the assessment period, these management practices will be implemented, and will subsequently be improved and tailored based on the results of the assessment. Also, the co-permittees will continue to identify and implement short-term feasible and reasonable sediment management practices that are practical for their respective agencies. As recognized by RWQCB staff, proper implementation of the new and redevelopment measures should ameliorate many of the water quality flow and sediment concerns in the watershed.

Project Goal

The goal of the Sediment Management Practices Assessment is to 1) determine practices that are implemented, planned, or suggested and their effectiveness to control, reduce, or eliminate sedimentation impairments in the San Francisquito Creek watershed; 2) define reasonable management measures deemed necessary to prevent or reduce excess sediment impairment in San Francisquito Creek from anthropogenic sources; and 3) implement those management measures as recommended by the watershed analysis and assessment of management practices.

Project Objectives

The objective of the Sediment Management Practices Assessment is to identify ongoing and planned erosion control measures and sediment management practices in the San Francisquito Creek watershed, and evaluate these activities for benefits and effectiveness by conducting the following:

- inventory sediment management practices undertaken by the co-permittee agencies,
- compile and review existing data for performance measures;
- identify possible management practices to be implemented in the future; and
- define feasible and reasonable sediment management measures and implement those necessary to prevent or reduce excess sediment impairment due to anthropogenic sources.

Project Scope

Task 1. Inventory and Document Sediment Management Practices in the Watershed

Survey jurisdictions, agencies and large landowners within the watershed to assess current management practices. Determine current and planned erosion control measures and sediment management practices in the watershed, the lead agency, regulatory/management driver, purpose and scope, location and extent, and time period. Management practices and control measures include planning activities and regulatory actions to reduce non-point sources of sediment; management of large woody debris and in-channel vegetation; and implementation of Best Management Practices (BMPs) in areas, such as streambank stabilization efforts, trail and rural road erosion control and prevention, new and redevelopment construction, and livestock management. List management practices that are currently being implemented, which management practices could be implemented on a wider scale, and planned measures that will be initiated prior to completion of the watershed analysis study (September 1, 2004). Review available project reports, interview agency staff, and search available records and databases for management activities.

Develop Work Product: Table presenting management practices, lead agency, driver, purpose/scope, stream reach, and schedule.

Funding/Resources. The estimated level of effort for Task 1 is 120 labor hours. Funding will be supported in part by the Prop 13 Grant (Task 6), and with matching funds and in-kind services by the SCVURPPP and SM-STOPPP co-permittees. The task will be conducted primarily by the Prop 13 grant project contractor, in a coordinated effort utilizing technical services of the stakeholder work group.

Task 2. Compile and evaluate existing information and data.

Using data gathered from Task 1, evaluate documented evidence and qualitatively determine ability of management efforts to improve impairment or prevent degradation of the waterbody due to sediment, in order to determine measures of success of management practices (performance measures). Incorporate results of the Prop 13 Grant Project Task 4 – Existing Conditions Analysis, as well as findings and recommendations from other efforts such as the WMI San Francisquito Creek Pilot Assessment, SCVURPPP and WMI LUS (Development Policies Comparison), and the FishNet4C regarding reviews on planning and management measures. Develop criteria for evaluation of management practices for effectiveness and to insure the adequacy of erosion and sediment control measures. Conduct evaluation of management practices and policies, and effectiveness of BMPs that are currently being implemented and additional BMPs that will be implemented to prevent or reduce sedimentation. Consider adequacy of project monitoring and maintenance, reporting, training, and education and outreach.

Develop Work Product: Table presenting data from project records and agency information on performance measures for each reach.

Funding/Resources. The estimated level of effort for Task 2 is 120 labor hours. Funding will be supported in part by the Prop 13 Grant (Tasks 4 and 6), and with matching funds and in-kind services by the SCVURPPP and SM-STOPPP co-permittees. The task will be conducted primarily by the Prop 13 grant project contractor, in a coordinated effort utilizing technical services of the stakeholder work group.

Task 3. Identify potential management practices to be implemented in the future.

Based on the information review, summarize areas where sediment problems occur, and no management actions are planned or implemented. Incorporate results of the Prop 13 grant watershed sediment assessment study and rapid sediment budget analysis, identifying existing and potential anthropogenic sources of erosion and sedimentation, and evaluate effectiveness of current management practices. Consider the findings and recommendations from other efforts such as the WMI San Francisquito Creek Pilot Assessment, SCVURPPP and WMI LUS (Development Policies Comparison), and the FishNet4C regarding reviews on planning and management measures.

Identify possible management practices to address sediment problem areas, including improvements to current management practices. Possible management measures and Best Management Practices may include, but are not limited to, the following: municipal maintenance, rural road maintenance, facility design, construction management and inspection, and parks/open space/land management practices. Recommended policy development may include: land use and management, flooding issues, and enforcement. Consider project monitoring and maintenance, reporting, training, and education and outreach requirements of possible projects.

Determine additional data and information needs to consider applicability of possible management practices, and list management practices that will require further analysis. Gather input from stakeholders, resource experts, and agency professionals to identify and determine the practicality of implementing additional management practices to protect, enhance, or restore the water quality or habitat impacted by sediment impairment (e.g. advantages, disadvantages, maintenance, performance, cost). Coordinate and collaborate with sediment assessment project and modeling efforts, to simulate land use management scenarios and effects of management practices.

Develop Work Products:

(1) Draft recommended projects list of recommended management measures and Best Management Practices

(2) Prepare draft and final management measures assessment report, that includes tables developed in task 1, 2, and 3, and addresses knowledge gaps and integration with results of ongoing studies, including the sediment assessment and rapid sediment budget analysis, habitat assessment and limiting factors analysis, SCB-WMI watershed pilot assessment, and the watershed council LTMAP studies. The assessment report will discuss the current and planned management practices in the watershed, and how they influence stream quality and address sediment impairment. The report will provide recommendations of additional management practices to address the causes of sediment impairments.

Funding/Resources. The estimated level of effort for Task 3 is 240 labor hours. Funding will be supported in part by the Prop 13 Grant (Task 7), and with matching funds and in-kind services by the SCVURPPP and SM-STOPPP co-permittees. The task will be conducted primarily by the Prop 13 grant project contractor, in a coordinated effort utilizing technical services of the stakeholder work group.

Task 4. Implementation Plan of Management Measures

Based on the results and recommendations of Task 3, prioritized recommendations for management of sources and impacted areas shall be developed, ranked according to potential benefit to steelhead and other sensitive species, reduction of flooding, and on a cost/benefit basis. Determine a schedule for implementation of the above management measures to reduce sediment. Incorporate implementation plan of management measures into watershed stewardship plan. Coordinate and collaborate with stakeholder groups and provide for public participation in plan development. Include process to identify partners and funding sources. As outlined in the Implementation Plan, the co-permittees shall implement those additional feasible and reasonable measures deemed necessary to prevent or reduce excess sediment impairment in San Francisquito Creek. The stakeholders will present those implementation measures to the Regional Board for review prior to implementation.

Develop Work Products:
(1) Prepare Implementation Plan of recommended projects with schedule, time frame, responsible parties and costing.

Funding/Resources. The estimated level of effort for Task 4 is 156 labor hours, excluding the work allocation for implementing the management measures. Funding of the Implementation Plan and Management Measures Task will be supported in part by the Prop 13 Grant (Tasks 7 and 8), and with matching funds and in-kind services by the SCVURPPP and SM-STOPPP co-permittees. The task will be conducted primarily by the Prop 13 grant project contractor, in a coordinated effort utilizing technical services of the stakeholder work group. The SCVURPPP and SM-STOPPP co-permittees are committed to implementing those additional feasible and reasonable sediment management measures identified in the assessment and implementation plan. .

Project Level of Effort

The estimated project level of effort for the Sediment Management Practices Assessment is 636 hours. The project budget cost estimate will be developed following finalization of the Prop 13 Grant Project scope and consultant contract. Prop 13 Grant matching funds are not yet determined under the grant process as of date of this work plan. The level of effort estimate does not include efforts associated with ongoing projects and activities in the watershed, including USGS Include, SCVWD, Stanford University, the City of Palo Alto, and the County of Santa Clara.

Project Schedule

The following table presents the anticipated project schedule for conducting the Sediment Management Practices Assessment. The actual project schedule and level of effort is dependent on the scope and subsequent completion and results of the Prop 13 Grant Project. The schedule assumes a start date of March 1, 2003 with a final management practices assessment report and implementation plan submittal to the Regional Board by April 1, 2004, and a project completion by September 1, 2009.

Table 1. Sediment Management Practices Assessment Project Milestones

Activity	Deliverable	Start Date	Completion Date
Task 1. Inventory management practices	Table of management practices	Mar 1, 2003	Sep 1, 2003
Task 2. Compile and evaluate existing information	Table of performance measures of implemented efforts	Sep 1, 2003	Apr 1, 2004
Task 3. Identify potential sediment management practices	Table of recommend management measures	Apr 1, 2004	Sep 1, 2004
Task 4. Develop Implementation Plan and Sediment Management Practices Assessment report	Implementation Plan and Draft and Final Report	Apr 1, 2004	Sep 1, 2004
Implement feasible and reasonable sediment management measures as recommended in Implementation Plan and Sediment Management Practices Assessment report		Sep 1, 2004	Sep 1, 2009

Table 2. SCVURPPP Co-Permittees Current Sediment Management Practices

Program/Activity	Description	Comments
City of Palo Alto		
Compliance Site Inspection and Storm Water Pollution Prevention Plan Compliance Assurance	The primary goal of the inspection and enforcement program is to prevent sediment from running off a construction site.	
Industrial inspections conducted by the entire Environmental Compliance Division	Inspect industrial and commercial sites for sanitary sewer or other purposes.	Potential sediment problems are investigated at the following example areas: materials storage areas, dumpster areas, and vehicle and equipment areas. Enforcement follow-up is conducted as appropriate.
Ordinance Enforcement	Section 16.09.117 - must have a SWPPP on sites equal to or greater than 5 acres. Section 16.09.117 - prior approval must be obtained from the city engineer or designee to discharge water pumped from construction sites to the storm drain. Section 16.09.061 - authority to monitor discharges and issue compliance directives. Section 16.09.106 - addresses illegal and threatened discharges to storm drains, gutters, creeks, or San Francisco Bay.	Palo Alto Municipal Code provisions are used to take appropriate formal enforcement action for sediment control.
Grading Ordinance	Section 16.28.120 – interim and final erosion and sediment control and storm water pollution prevention plans must be prepared, approved, and implemented when a grading permit is needed.	Palo Alto Municipal Code provisions are used to take appropriate formal enforcement action for sediment control.
Outreach	Outreach efforts to raise awareness about sediment control associated with San Francisquito and other creeks.	

Program/Activity	Description	Comments
Santa Clara Valley Water District		
Stream Maintenance and Annual Sediment Removal	Performs sediment removal and bank protection activities within the District's jurisdiction, includes sediment removal, bank stabilization, vegetation/erosion control, management of large woody debris and live vegetation.	Involves environmental assessments and obtaining regulatory permits. Bank stabilization, erosion control, and sediment removal occur as problems arise. *History of District activity in watershed for last 5 years (?):* • 1997 • 1998 • 2000
Capital Improvement Project	Implementation of flood protection supply projects: • Levee Restoration Project • Flood Management Project	Involves planning, design, construction, and environmental assessment processes.
Comprehensive Flood Management Protection (CFMP)	Develops and implements a comprehensive flood protection and stream stewardship program supported by project-specific stakeholders	San Francisquito Creek work is overseen by the Joint Powers Authority, District is signatory member
Non-point source Pollution Prevention Program	Preventing pollution of storm water runoff through SCVURPPP activities and District-specific activities and operations	Involves District participation in the San Francisquito Creek Watershed Sediment NPDES permit provisions.
Surface Water Quality Improvement Program	Development and implementation of monitoring and assessment projects to minimize or eliminate impacts of pollutants including sediment, address problems, support management measures, and evaluate performance measures.	Involves District participation in the San Francisquito Creek Watershed Sediment Assessment work.
San Francisquito Creek Sediment Study	Support development of sediment TMDL, sediment assessment, and management practices assessment.	Involves performing aquatic habitat assessment and limiting factors analysis for steelhead
Water Resource Protection Ordinance	An ordinance of District defining agency's water resource jurisdictional limits of flood control responsibility; providing for maintenance of watercourses, for joint use of projects; prohibiting pollution of District water supplies and encroachment with watercourses	WRPO Collaborative formed of community, municipal, and county staff. District working with Collaborative regarding planning and permit review.
Regional Stormwater Management Program – Hydromodification Planning (HMP)	District with SCVURPPP investigating hydromodification and stream stability due to development; developing regional solutions for management of peak flow and runoff, reduce instream erosion and increase stream stability	

SCB-WMI	Development and implementation of watershed management approach to address water quality issues through stakeholder forum.	Sediment TMDL stakeholder workgroup within WMI (SOILS)
County of Santa Clara		
Rural Public Works Maintenance	Update of rural maintenance Performance Standards and Drainage Manual	Large woody debris is addressed as a "permit" requirement in the recently submitted Rural Public Works Guidance Manual and Performance Standards.
Livestock Advisory Program	Provides information and assistance regarding livestock stewardship issues to rural landowners such as livestock handling, land management, and water management.	
Grading Ordinance (see sections C12-411, C12-435(d), and C12-517)	Use of Best Management Practices (BMPs) for erosion prevention and sediment control reduces the sediment load in local waterways.	
New Development, Use Permit, Environmental Review	Evaluation of the potential impact of a proposed development project upon the environment	
Riparian Protection Ordinance	County of Santa Clara Riparian Corridor Study: A Background Document for the Development of a Riparian Protection Ordinance for the County of Santa Clara	Document by the County of Santa Clara Planning Office

Attachment A

Sediment Management Practices of the Santa Clara Valley Water District

This section briefly describes the sediment removal and sampling activities of the Santa Clara Valley Water District (District), and documents the types and sources of relevant sediment data collected. The District conducts routine maintenance activities that include sediment removal and erosion control, and constructs flood protection facilities, water utility facilities, and facility-related projects in the San Francisquito Creek Watershed that may include sediment removal or stabilization of sediment sources. The District Stream Maintenance Program encompasses the implementation of routine stream and facility maintenance work, and includes sediment removal, stream bank protection and vegetation management.

Sediment Removal

Sediment removal is the act of mechanically removing sediment deposited within a stream or a facility. It is removed when it (1) reduces capacity, (2) prevents facilities or appurtenant structures from functioning as intended, or (3) impedes fish passage and access to fish ladders. In order to properly dispose of excavated sediments, routine characterization of representative samples is conducted. The samples are collected and analyzed according to state and federal regulations, and generally include analyses of the samples for total mercury.

The District's purpose for performing sediment removal activities is to ensure that a stream will remain within its banks and to ensure that appurtenant facilities are working as designed. Sediment is most often removed from modified channels; sediment is also removed from natural creeks on an occasional basis to provide proper functioning of outfalls, culverts, bridge crossings and stream gauging stations, and from other facilities such as fish ladders, fish screens, percolation ponds, water diversion structures and canals.

The Santa Clara Valley Water District estimates that it removes an average of 80,000 cubic yards of sediment on about 17 miles of channel per year in Santa Clara County. This average includes both concrete-lined and earth-lined channels. This is an average annual quantity and will vary from year to year. For example, in 1986, 176,800 cubic yards of sediment were removed from creeks in Santa Clara County. In 1992 only 44,700 cubic yards of sediment were removed.

In the San Francisquito Creek Watershed, silt was removed in 1984 (3,290 cy), 1993 (1,260 cy), and again in summer/early fall of 1997 (4,600 cy). During the winter of 1997-1998, sediment was removed on an emergency basis on two occasions (a total of 1,500 cy). In 2000, about 4000 cy of sediment was removed by the District along a 400 linear feet reach.

Stream Bank Protection

Stream bank protection involves an action by the District to repair erosion. The District implements stream bank protection when the problem (1) causes or could cause significant damage to a property or adjacent property, (2) is a public safety concern, (3) negatively affects transportation or recreational use, (4) negatively affects water quality, or (5) negatively affects riparian habitat. Repairs may take several forms from installing "hard" structures (e.g., rock, concrete, sack concrete, gabions) to "soft" structures (e.g., willow brush mattresses, log crib walls, pole plantings). Generally, sediment disposal is not required for these projects, and laboratory analyses of sediment samples is not conducted.

Bank protection work may either occur as repair of an existing bank protection project which is failing, or as new work along a bank which is eroding. The new work is considered routine maintenance work because it is either restoring the flood control function of an engineered channel or it is repairing a non-engineered bank to its approximate condition prior to becoming an erosion problem. Erosion on banks may cause vegetation and soil loss, damage to private or public property, transportation impacts, safety hazards, turbidity injurious to fish and aquatic life, and sedimentation downstream. Levee erosion may lead to failure of the structure and flooding in addition to the impacts caused by bank erosion, including damage to public utilities. Most often, bank protection projects are implemented in the dry season (summer), unless an immediate or emergency response is required as a result of bank failure during the wet season.

Hazardous Materials Investigations

The District is responsible for providing the necessary lands, easements, and right-of-ways along the channel prior to construction of flood protection or water utility facilities. Before construction, the District performs Phase I/II Hazardous Substance site investigations, which include the sampling and analysis of surface sediments, soil-borings, monitoring well cores, and excavation sites. The Phase II investigations are conducted to characterize and delineate the lateral and vertical extent of contaminated soil where flood control improvements are planned. The data are used to classify hazardous materials for disposal, identify soil management alternatives and develop cost estimates for remediation and soil disposal. In addition, the investigations provide project management alternatives related to property acquisition, worker health and safety, and residuals management during construction. The samples are collected and analyzed according to state and federal regulations, and generally include analyses of the samples for petroleum hydrocarbons.

DISTRICT RELATED PROGRAMS AND PROJECTS

This following provides an overview of the linkages between the Stream maintenance Program in the San Francisquito Creek watershed and stream-related programs and projects now underway at the District:

1. Annual maintenance work (work conducted in 1998, 1999 and 2000)
2. Capital Improvements Program (CIP, various District project numbers)
3. Comprehensive Flood Management Program (CFMP, District Project No. 000404)
4. Nonpoint Source Pollution Protection Program (NPS Program, District Project No. 007902)
5. Surface Water Quality Improvement Program (Clean Safe Creeks and Natural Flood Protection, District Project No. 267543)
6. San Francisquito Creek Sediment Study (Clean Safe Creeks and Natural Flood Protection, District Project No. 267542)
7. Santa Clara Basin Watershed Management Initiative (SCBWMI, District Project No. 0007914)

1. Annual Maintenance Work (1997, 1998 and 2000)

Purpose: Like the Stream Maintenance Program, this work involved preparing environmental assessments and obtaining regulatory clearances for sediment removal and bank protection activities within the District's jurisdiction. However, these annual projects did not include ongoing vegetation management work because it does not require USACE permits, and Vegetation Management staff avoided locations with ESA issues.

2. Capital Improvements Program (CIP, various District project numbers)

Purpose: Implement needed flood protection supply projects through planning, design, construction, and environmental assessment processes.

3. **Comprehensive Flood Management Project (CFMP, District Project No. 000404)**

   Purpose: The mission of the CFMP is to develop and implement a comprehensive flood protection and stream stewardship program supported by the community, and to secure the funding necessary for the implementation of that program. This project seeks to expand flood protection goals into a larger stream management program. The program outcomes and activities will be consistent with the following ends policies adopted by the Board of Directors for flood protection and stream stewardship:

   - Homes, schools, businesses, and transportation networks are protected from flooding and erosion.
   - Clean, safe water in our creeks and bays.
   - Healthy creek and bay ecosystems are protected, enhanced, or restored as determined appropriate by the Board of Directors.
   - Additional open spaces, trails, and parks along creeks and in the watersheds when reasonable and appropriate

   Participants: Project-specific stakeholders including District management and staff, community stakeholders, environmental advocacy groups, and local government representatives. Most projects are fully within the District's jurisdiction, while San Francisquito Creek work is overseen by a Joint Powers Authority, and stream stewardship projects will involve partnerships with local governments, open space districts and community organizations.

4. **Nonpoint Source Pollution Prevention Program (NPS Program, District Project No. 007902)**

   Purpose: To protect aquatic habitat, recreational water uses, and local water supply by preventing pollution of storm water runoff. The NPS Program is comprised of: (1) "areawide" activities performed collaboratively with 14 other agencies in northern Santa Clara County under the Santa Clara Valley Urban Runoff Pollution Prevention Program and (2) "District-specific" activities performed uniquely by the District for its own operations and within its own jurisdiction.

   The NPS Program reduces the flow of all pollutants from diffuse sources into streams, reservoirs, and the San Francisco Bay. The reduction of sediment, metals, and organic pollutants improves water and aquatic habitat quality.

5. **Surface Water Quality Improvement Program (Clean Safe Creeks and Natural Flood Protection, District Project No. 267543)**

   Purpose: In coordination with state, local, and District programs, develop and implement monitoring and assessment projects to minimize or eliminate the impacts of pollutants to the environment, to describe status and trends, to address existing and emerging problems, to support management and regulatory programs, and to evaluate performance measures.

6. San Francisquito Creek Sediment Study (Clean Safe Creeks and Natural Flood Protection, District Project No. 267542)

Purpose: To identify and quantify sources of sediment loadings and land use contributions in the San Francisquito Creek watershed. The sediment assessment will be used to develop implementable actions, based on science, that will address impacts from sedimentation on fisheries, aquatic habitats, and flood conveyance, as well as other beneficial uses designated for San Francisquito Creek.

Goals of the San Francisquito Creek Sediment Study include:

- Conduct sediment assessment and watershed analysis, to identify and quantify sources of sediment loadings, and proportional land use contributions.
- Use the sediment assessment to develop erosion control and prevention plan, that will address impacts from sediment on fisheries, aquatic habitats, and flood conveyance.

The watershed sediment assessment and analysis, which includes the development of a rapid sediment budget, will be conducted in order to develop an erosion control and prevention plan. The sediment assessment will assist in the evaluation of appropriate and feasible management practices to be implemented to prevent and reduce excess sediment production to streams, enhance aquatic habitat, and reduce flood hazards.

7. Santa Clara Basin Watershed Management Initiative (WMI, District Project No. 0007914)

Purpose: The mission of the WMI is to protect and enhance the watershed, creating a sustainable future for the community and the environment. The participants will work toward the development and implementation of an integrated watershed management approach to address water pollution and improve the condition of the Santa Clara Basin. Investigation and implementation measures related to Total Daily Maximum Loads (TMDLs) for pollutants of impaired waterways are currently under the WMI umbrella, however they may soon become one or more separate projects based on the pollutants to be reduced.

Attachment B

Sediment Management Practices of the County of Santa Clara

Rural Public Works Maintenance – Update of Performance Standards

Drainage Manual

Livestock Advisory Program

Grading Ordinance (see sections C12-411, C12-435(d), and C12-517)

New Development, Use Permit, Environmental Review

Attachment C

Sediment Management Practices of the City of Palo Alto

1) Construction Site Inspection and Storm Water Pollution Prevention Plan Compliance Assurance

The primary goal of the inspection and enforcement program is to prevent sediment from running off a construction site. Palo Alto staff visits the following sites as needed during and after the construction period:

NOI sites (>5 acres)
Complaints (citizen)
Patrol - single family construction sites
Referrals from City crews
Sites where P.W. Engineering reviewed grading plans and a Storm Water Pollution Prevention Plan was established.
Revisit problem sites

When Ordinance Violations are discovered, all construction sites are subject to:

Verbal Warnings-cases where a threatened discharge is about to happen or a minor occurrence can be corrected immediately.
Compliance Directive - repeat occurrence or to correct a repeat occurrence of a threatened discharge.
Notice of Violation - follows the issuance of a Compliance Directive. Violator's name is entered into the database.
Fines - issued to repeat violators, gross violators, and violators who are believed to ignore storm water best management practices and PAMC ordinance.

2) Industrial inspections are conducted by the entire Environmental Compliance Division when inspecting industrial/commercial sites for sanitary sewer or other purposes. Potential sediment problems are investigated at the following example areas.

Materials Storage Areas
Dumpster Areas
Vehicle and Equipment Areas

Enforcement follow-up is conducted as appropriate.

3) Ordinance Enforcement

The following key Palo Alto Municipal Code provisions are used to take appropriate formal enforcement action for sediment control:

Section 16.09.117 - must have a SWPPP on sites equal to or greater than 5 acres.

Section 16.09.117 - prior approval must be obtained from the city engineer or designee to discharge water pumped from construction sites to the storm drain.

Sediment Management Practices of the City of Palo Alto (continued)

Section 16.09.061 - authority to monitor discharges and issues compliance directives.

Section 16.09.106 - addresses illegal and threatened discharges to storm drains, gutters, creeks, or San Francisco Bay.

Grading Ordinance

Section 16.28.120 – interim and final erosion and sediment control and storm water pollution prevention plans must be prepared, approved, and implemented when a grading permit is needed.

4) Outreach – The City of Palo Alto conducts many outreach efforts to raise awareness about sediment control associated with San Francisquito and other creeks. By raising awareness, a higher level of compliance with sediment control requirements is achieved. The City utilizes brochures for construction contractors and project managers concerning earthmoving, saw cutting, concrete work, construction dewatering, materials storage and other specific operations, which can cause sediment. Other information is targeted for commercial business managers that might be involved in construction work, or other types of work that may lead to sediment pollution. Residents and school children are also targeted with outreach messages to solicit their help in sediment control. All City staff is asked to report problems that they see so that Environmental Compliance Staff can take appropriate enforcement action. City Vehicle dashboards show the number to call to report storm drain pollution problems. Cameras have been placed in City Vehicles so that any Staff member can document problems for follow-up by Environmental Compliance Staff.

Attachment D

Erosion Control and Prevention Plan, San Mateo County STOPPP

(submitted to Regional Water Quality Control Board, September 2001)

County of San Mateo

San Francisquito Creek Watershed Erosion Control and Prevention Plan

September 1, 2001

County of San Mateo

Current Erosion Control and Prevention Measures

Program/Activity	**Description**	**Comments**
Fishery Network of Central California Coastal Counties (FishNet 4C)	Consortium of 6 counties dedicated to preserving and restoring anadromous fish habitat	San Mateo County is a founding member of this organization, and continues to provide staff and funding for its efforts.
Fishnet 4C Assessment Report "Effects of County Land Use Policies and Management Practices on Anadromous Salmonids and Their Habitats"	This evaluation of County policies and practices resulted in a list of recommendations to the Board of Supervisors. The Board of Supervisors has directed staff to address four priorities identified by the report, as tabulated below:	County staff have been active in addressing the priorities before and since the report was presented to the Board of Supervisors in April 2001. Progress made on each of the priorities is listed below.
Mapping	Prepare and distribute a map depicting streams that provide habitat for anadromous fishes.	Mapping of priority watersheds for restoration of coho salmon and steelhead trout habitat has been completed in consultation with the National Marine Fisheries Service.
Riparian Buffer Zone – San Francisquito Creek	Establish a watershed overlay district that will require riparian corridor mapping, buffer zones and performance standards within the San Francisquito Creek watershed.	A zoning ordinance amendment creating the watershed overlay district is currently being considered by the Planning Commission.
Improve Enforcement Capabilities	Review and improve, where possible, enforcement options to ensure compliance with existing County regulations intended to protect natural resources.	Representatives from the Planning Department, Public Works, Environmental Health, Parks and County Counsel are evaluating existing enforcement capabilities, and will recommend upgrades to the Board of Supervisors.
Performance Standards for Road and Facility Maintenance	Develop and implement performance standards for maintenance activities that potentially impact water quality and/or sensitive habitats.	The County has implemented written performance standards for road and facility maintenance that will benefit aquatic resources. All Public Works and Parks maintenance staff have received training on the standards. The standards were submitted to the Regional Water Quality Control Board in compliance with

Current Erosion Control and Prevention Measures (continued)

Program/Activity	Description	Comments
Performance Standards for Road and Facility Maintenance (cont.)		Provision C.9 of the County-wide NPDES permit. The standards are currently being expanded to include the full range of maintenance activities.
Water Pollution Control for Public Construction	Specifications and management practices required of contractors bidding on public construction projects.	The draft specifications and drawings are in use by Public Works on projects in the Coastal Zone, and will be revised and adapted for use in other areas as needed.
Grading Permit Standards	Requirements enacted by the County to ensure that site grading activities are conducted in a manner that will not degrade aquatic resources.	Enforcement provisions are currently under review.
Stormwater Management and Discharge Control Ordinance	Requirements enacted by the County that prohibit non-stormwater discharges to any county storm drain	Includes best management practices for new development. BMPs are currently under review.
Heritage and Significant Tree Ordinance	Requirements enacted by the County to prohibit cutting or removal of various tree species without a permit.	Includes requirements for replacement tree planting.

Interim Erosion Control and Prevention Measures

The County of San Mateo will be participating with the other co-permittees to accomplish a watershed assessment and rapid sediment budget for San Francisquito Creek. The assessment project, which may be funded in part by Proposition 13 grant funds administered by the Regional Board, is expected to be completed in 2003. During the study period, the County anticipates implementing the following interim erosion control and prevention measures, in addition to those currently in place.

Program/Activity	**Description**	**Comments**
Standards for Design and Construction	A guidebook, to be adopted by the Board of Supervisors, that includes accepted methods for erosion and sediment control, water pollution control, streambank stabilization, revegetation, and other types of construction in sensitive areas.	County departments are presently assembling all current guidelines, checklists and management practices used in the design, construction and permitting processes. The material will be updated and assembled into one coherent document for use by County staff and the public to ensure resource protection.
Performance Standards for Road and Facility Maintenance	Develop and implement performance standards for maintenance activities that potentially impact water quality and/or sensitive habitats.	The standards will be continually updated to reflect current technology in erosion and sediment control and water quality controls. Staff training will be provided on an annual basis, and reports submitted as described in the Maintenance Standards submitted to the Regional Board in February 2001.
Huddart and Wunderlich County Parks Road and Trail Assessments	Analyze existing road and trail conditions, propose and implement upgrade measures.	The County Parks Department is applying for grant funding to perform this work.

Final Erosion Control and Prevention Plan

The watershed assessment and rapid sediment budget (Proposition 13 project) mentioned above is expected to be completed in 2003. The final report will contain recommendations for implementing specific practices, managing particular areas within the watershed and prioritizing projects. The County will continue to address the recommendations of the FishNet 4C assessment report mentioned at the beginning of this section while the watershed assessment is underway. The watershed assessment may reveal additional deficiencies in the County's current land management policies and practices and propose changes to those practices. Those proposals will be carefully evaluated at the conclusion of the study and implemented as appropriate.

Inventory of Potential Sediment Sources

Existing and potential sediment sources will be cataloged during the watershed assessment (Proposition 13 project) and repair schemes will likely be proposed. The County has identified Huddart and Wunderlich Park trails as potential sediment sources, and is attempting to secure funding to assess the condition of the trails and to identify and implement potential treatments.

Other sediment sources which may be identified during the assessment study period will be addressed on a case-by-case basis. Examples may include roadside slipouts or damaged culverts during storm periods. Those repairs are generally accomplished as soon as permits can be obtained and weather allows.

CERTIFICATION

I hereby certify that the information contained in the San Francisquito Creek Erosion Control and Prevention Plan, Final Report, September 1, 2001, prepared for the unincorporated area that is within the San Francisquito Creek watershed, to the best of my knowledge is accurate and complete; that the San Mateo County Board of Supervisors, acting as the governing Board of the San Mateo Flood Control District ("District"), is an active member of the San Francisquito Creek Joint Powers Authority (JPA) and has committed funds for the continuation of its membership in the JPA through June 2002; that the District has agreed to participate in and finance a share of a watershed assessment, including the development of a rapid sediment budget; and that the District will continue to work with the Cities/Towns of East Palo Alto, Menlo Park, Palo Alto, Portola Valley and Woodside to cooperatively address water quality issues in the watershed.

NEIL R. CULLEN, DIRECTOR OF PUBLIC WORKS

SIGNATURE:

DATE: 8/30/01

California Regional Water Quality Control Board
San Francisco Bay Region

nston H. Hickox
Secretary for Environmental Protection

Internet Address: http://www.swrcb.ca.gov
1515 Clay Street, Suite 1400, Oakland, California 94612
Phone (510) 622-2300 • FAX (510) 622-2460

Gray Davis
Governor

Date: July 8, 2002
File: 2182.05 (JBO)

Mr. Beau Goldie
Management Committee Chair-SCVURPPP
Santa Clara Valley Water District
5750 Almaden Expressway
San Jose, CA 95118-3614

SUBJECT: Comments on the Sediment Management Plan for San Francisquito Creek, Section 3, Volume II of FY 02-03 Work Plan

Dear Mr. Goldie and Co-permittees:

We have reviewed the Santa Clara Valley Urban Runoff Pollution Prevention Program's (Program) Sediment Management Plan for San Francisquito Creek. We support the Co-permittees participation in the stakeholder process and their cooperative work in developing a watershed approach to sediment assessment and analysis to determine sediment impacts in the watershed. However, we are concerned that implementation of erosion reduction management measures is not being implemented at the same time that sediment assessment is moving forward. Through the sediment Total Maximum Daily Load (TMDL) process, we are taking a two-pronged approach to restoring beneficial uses: (1) technical analysis, including problem definition, sources assessment, linkage analysis, allocation, and (2) implementation. We are striving to move forward in assessment and implementation simultaneously.

The Sediment Management Plan for San Francisquito Creek (Plan) satisfies only the first portion of Provision C.9.f.ii. of the Program's permit. The Plan provides for an inventory of management practices, compilation and evaluation of existing information, identification of sediment management practices, and development of an implementation plan and management practices assessment report. It does not, as Provision C.9.f.ii. requires, implement additional management practices necessary to prevent or reduce excess sediment impairment in San Francisquito Creeks. Such management practices may include but are not limited to: management of large woody debris and live vegetation in and around channels; streambank stabilization projects; road construction, operation, maintenance, and repairs to prevent and control road-related erosion; management of construction related sediment; and management of post-construction sediment from areas of new development or redevelopment. The implementation of additional management practices must be added to the Plan, as further described below.

The Plan's Project Goal (page 4) is as follows:

> "The goal of the Sediment Management Practices Assessment is to determine practices that are implemented, planned, or suggested and their effectiveness to control, reduce, or eliminate sedimentation impairment in the San Francisquito Creek watershed."

Language such as "*and implement any additional management practices necessary to prevent or reduce excess sediment impairment in San Francisquito Creek*" should be added to the Project Goal to demonstrate that all Provision C.9.f.ii. requirements will be met.

Similarly, language such as "*- Implement measures necessary to prevent or reduce excess sediment impairment in San Francisquito Creek*" should be added to the Project Objectives, also on page 4 of the Plan. The addition of this Project Objective would be consistent with the four tasks defined in the Plan, specifically Task 4 (page 7).

Task 4 (Implementation Plan of Management Measures) does not include a commitment to implement sediment reduction measures. While we support identification and prioritization of effective implementation measures, a mechanism to ensure that implementation actually occurs is needed also. Task 4 states that implementation will be dependent on funding availability and will be undertaken by an undefined collaboration with others. However, the Co-permittees must commit to funding the implementation of sediment reduction measures. Task 4 must be expanded to include a commitment to implement management practices and creek restoration. Table 1 must include a task for Implementation of Management Measures and identify a schedule for completion.

In summary, the Plan must be revised to include implementation of additional management practices, as described above. Please submit the revised Plan by October 15, 2002. If you have any questions concerning this matter, please contact Jan O'Hara of my staff at (510)622-5681, or email at jbo@rb2.swrcb.ca.gov.

Sincerely,

--original signed by--

Loretta K. Barsamian
Executive Officer

cc: Adam Olivieri, EOA, Inc.
Jill Bicknell, EOA, Inc.
Joe Teresi, Palo Alto
Steve Homan, Santa Clara County

- for Dioxin-like Compounds: submit plan with implementation schedule by March 1, 2004; begin implementation by July 1, 2004 although implementation of early action priorities should take place before that date

The Dischargers may coordinate with other stormwater programs and/or other organizations to implement cooperative plans and programs to facilitate implementation of the specified actions.

By Sept 1 2003
per letter
to STOPPP
from Reg Bd

f. **Control Program for Sediment.** The Dischargers shall conduct analyses of excess sediment impairment in urban streams and assess management practices that are currently being implemented and additional management practices that will be implemented to prevent or reduce excess sediment impairment in urban creeks, and implement any additional management practices necessary to prevent or reduce excess sediment impairment in urban creeks in accordance with the following:

i. **San Francisquito Creek.** Submit a plan and time schedule for implementation acceptable to the Executive Officer by September 1, 2001 to conduct a watershed analysis of San Francisquito Creek in cooperation with the San Mateo Countywide Stormwater Pollution Prevention Program (STOPPP). The plan will provide for: (1) quantitative characterization of sediment and water inputs to the creek; (2) relative roles of sediment associated with natural and anthropogenic land use discharges; (3) sediment conveyance from headwaters to the Bay, and (4) development of a rapid sediment budget.

ii. **San Francisquito Creek.** Submit a plan and time schedule for implementation acceptable to the Executive Officer by March 1, 2002 to conduct, in cooperation with STOPPP, an assessment of management practices that are currently being implemented and additional management practices that will be implemented to prevent or reduce excess sediment impairment in urban creeks, and implement any additional management practices necessary to prevent or reduce excess sediment impairment in San Francisquito Creeks. Such management practices may include but are not limited to: management and/or removal of large woody debris and live vegetation from channels; streambank stabilization projects; road construction, operation, maintenance, and repairs to prevent and control road-related erosion; management of construction related sediment; and management of post-construction sediment from areas of new development or redevelopment.

iii. Other Creeks. Submit a report acceptable to the Executive Officer by March 1, 2002 that identifies the other creeks that may be impaired by excessive sediment production from erosion due to anthropogenic activities.

Other Creeks. Submit a plan and time schedule for implementation acceptable to the Executive Officer by September 1, 2002 to conduct a watershed analysis and management practice assessment in the other creeks which may be impaired by excessive sediment production from erosion due to anthropogenic activities.

nta Clara Valley
a istrict

File

5750 ALMADEN EXPWY
SAN JOSE, CA 95118-3614
TELEPHONE (408) 265-2600
FACSIMILE (408) 266-0271
www.scvwd.dst.ca.us
AN EQUAL OPPORTUNITY EMPLOYER

October 15, 2002

Ms. Loretta K. Barsamian
Executive Officer
San Francisco Bay Region
Regional Water Quality Control Board
1515 Clay Street, Suite 1400
Oakland, CA 94612

Subject: Revised Work Plan for Assessment of Sediment Management Practices in San Francisquito Creek Watershed

Reference: Regional Water Quality Control Board letter, *Comments on the Sediment Management Plan for San Francisquito Creek, Section 3, Volume II of FY 02-03 Work Plan*, dated July 8, 2002 (File: 2182.05 (JBO))

Dear Ms. Barsamian,

I am pleased to submit the revised *San Francisquito Creek Watershed Assessment of Sediment Management Practices – Plan and Schedule*, for the assessment and implementation of sediment management measures in San Francisquito Creek Watershed, on behalf of the Santa Clara Valley Urban Runoff Pollution Prevention Program (SCVURPPP) and the San Mateo Countywide Stormwater Pollution Prevention Program (SM-STOPPP). This work plan fulfills SCVURPPP's Permit Provision 9(f) (*ii*) of Order 01-024 of the Regional Water Quality Control Board's (RWQCB) adopted on February 21, 2001, and fulfills SM-STOPPP's Permit Provision C. 10 of Order 99-059 of the RWQCB's adopted on July 21, 1999.

The submittal of this revised work plan is in response to the Regional Board's comment letter, dated July 8 2002 (referenced above), requesting the addition of language for the implementation of additional management practices be added to the plan as follows:

- add language to implement management measures to the project goal;
- add language to implement management measures to project objectives (e.g.Task 4);
- expand Task 4 to include a commitment to implement management practices; and
- add a task to implement management measures and identify a schedule for completion to Table 1 – Project Milestones.

The mission of the Santa Clara Valley Water District is a healthy, safe and enhanced quality of living in Santa Clara County through the comprehensive management of water resources in a practical, cost-effective and environmentally sensitive manner.

As the sediment assessment project and assessment of management measures moves forward, the co-permittees will continue to proceed with on-going or planned sediment management practices that are presented in Table 2. Also, the co-permittees will continue to identify and implement short-term feasible and reasonable sediment management practices.

In addition, an extension of the project schedule is requested to align with the schedule for the Sediment Reduction Plan developed under the Prop 13 Grant Project, as a result of delays in the Prop 13 Grant contract process at the State Water Resources Control Board. At the time of this submittal, the contract process has still not been finalized at the State office, causing the delay in the planned project start date by more than 12 months.

The work plan is submitted jointly by the co-permittees of the two Programs (SCVURPPP and SM-STOPPP) in the San Francisquito Creek watershed in order to provide a coordinated and cooperative effort by the two programs: County of San Mateo, City of East Palo Alto, City of Menlo Park, City of Portola Valley, City of Woodside, County of Santa Clara, City of Palo Alto, and Santa Clara Valley Water District. In addition, several agencies have also greatly contributed to the development of the Scope of Work including the United States Geologic Survey, the San Francisquito Creek Joint Powers Authority, Stanford University, the San Francisquito Creek Watershed Council, and CLEAN Southbay. We wish to thank these agencies for their participation in this coordinated effort and assisting in the development of the work plan.

If you have any questions concerning this matter, please contact Laura Young of my staff at (408) 265-2607, extension 2461, or email at lyoung@valleywater.org.

Sincerely,

Roger Narsim
Engineering Unit Manager
Countywide Watershed Programs Unit

Enclosure (1): Work Plan, revised October 15, 2002
Express Delivered on October 15, 2002

cc: Adam Olivieri (EOA), Program Manager, SCVURPPP
Robert M. Davidson, Program Coordinator, SM-STOPPP
SCVURPPP Co-permittees (see attached distribution list)
SM-STOPPP Co-permittees (see attached distribution list)

lcy:lcy
mgtplan.101502.SCVWDlet

__SCVURPPP Co-Permittees__

Laura Young
Santa Clara Valley Water District

Phil Bobel
City of Palo Alto

Joe Teresi
City of Palo Alto

Steve Homan
County of Santa Clara

__SM-STOPPP Co-Permittees__

Lisa Ekers
County of San Mateo

Dave Bishop
City of East Palo Alto

Dianne Dryer
City of Menlo Park

Kevin Rohani
City of Portola Valley

Christina Hovland
City of Woodside

bcc: R. Narsim, B. Calhoun, Distribution List

Laura Young

From: Laura Young
Sent: Friday, May 30, 2003 11:27 AM
To: Laura Young
Subject: FW: Reg Bd review and comment SF Creek workplan submittals
Importance: High

-----Original Message-----
From: Laura Young
Sent: Wednesday, January 08, 2003 4:20 PM
To: 'Adam W. Olivieri'; Beau Goldie; Roger Narsim; Brett Calhoun
Cc: 'Phil Bobel (E-mail)'; 'Steve Homan'; Jennie Micko; Patricia Showalter; Dipankar Sen
Subject: Reg Bd review and comment SF Creek workplan submittals
Importance: High

RE- submittal for provision 9(f)(ii)

I received comments from Regional Board (Jan O'Hara and Sandi Potter) on the Revised workplan submittal of the *San Francisquito Creek Watershed Assessment of Sediment Management Practices - Plan and Schedule, October 15, 2002.* Jan provided me informal, hand written comments yesterday (1/7/03) after BASMAA Monitoring meeting, and we met to discuss and go over them.

Adam/Beau - Is this OK or does the Program need official comment letter from Regional Board?

See my responses below. No date was discussed for this second revison.

Regional Board comments as follows:
1. We like the tables and encourage more use of tables.
LCY - I will put District actions in table format.

2. The SCVWD portion doesn't talk about what the District is doing (concrete). The text is vague or discusses grants rather than actions. See the table of specific actions: HMP, 83-2 Water Resources Protection Ordinance, Limiting Factors Analysis
LCY - I will state that bank stabilization, erosion control, and sediment removal occur as problems arise, and include history of District activity in watershed, last 5 years (?) - I'll check again with Jennie Micko's group. I will add HMP, 83-2, Limiting Factors Analysis - also watershed group's long-term assessment for flood control project.

3. We support parties working together to obtain the info needed for the TMDL: HMP, Limiting Factors study, JPA's SF Creek Watershed Assessment. The work plan should relect this.
LCY - Alot of this, stakeholders working together, was in the other workplan for the Sediment Assessment, but will also include in this one.

4. The schedule seems good through 9/1/04, but completion dates for implementaion must be moved up from 9/1/08 to 9/1/06, with monitoring to determine the effectiveness of implementation.
LCY - I don't know how to estimate completion dates for implementation when we don't know what all we're implementing yet. Can we complete implementation in 3 years? What about HMP and 83-2 - does District have an implementation schedule for these? Effectivness monitoring can be coordinated with monitoring for District's/COE long-term assessment for flood control project.

5. Per the permit, actions/planning must include management of large woody debris and live vegetation.
LCY - This will be evaluated by the consultants in implementing this workplan, but I will make it more clear.

6. The SCVWD portion of the work plan doesn't speak to the need for habitat.
LCY - This will be done by including the Limitng Factors Analysis, HMP, 83-2, CIP actions in items 2 and 3 above. I will include more text on habitat.

ALSO RE- submittal for provision 9(f)(i)
Jan hasn't reviewed the other workplan *San Francisquito Creek Watershed Sediment Assessment Workplan, August 31, 2001*. She apologized for that. Since I'm revising it to be in line with the consultant's scope and schedule from prop 13 grant, and changes to USGS work, she will now wait and review the revised version.

Laura Young
Santa Clara Valley Water District
408-265-2607 x2461

Upgrade Outlook® - Add icons to your Emails Click Here!
Outlook® is a registered trademark of Microsoft Corporation
HI! COOL! HELP! BYE!

Laura Young

From: Adam Olivieri [awo@eoainc.com]
Sent: Thursday, January 09, 2003 9:19 AM
To: Brett Calhoun; Laura Young; Beau Goldie; Roger Narsim
Cc: 'Phil Bobel (E-mail)'; 'Steve Homan'; Jennie Micko; Patricia Showalter; Dipankar Sen
Subject: RE: Reg Bd review and comment SF Creek workplan submittals

Laura - For most circumstances Brett is correct. If the Program and/or Co-permittees are required/expected to formally respond we need a formal letter from the RWQCB staff to the Management Committee Chair with a copy to the Program Manager. (There are circumstances where staff don't expect a formal response and are just providing general comments that can be addressed during the conduct of a study/project and the outcome (i.e., permit compliance) does not hinge on providing a formal response - however you still need to maintain a clear record of communication). You do not have to push the staff to put a formal date to respond in the their letter, rather I suggest that you request that it be left open for both parties to agree on a mutually agreeable time frame. The Program and/or Co-permittee response then should be formal and preferably follow the Program's process for responding (i.e., 1) work with the appropriate Adhoc group (if one exists) to prepare the response or get approval of your intended response, 2) distribute the letter to the Program Internal Review Committee for comment and approval (composed of the Beau, Lorrie, Randy and the West Valley MC member), and 3) Distribute a final copy of the response to the MC.)

Thanks
Adam O.

At 05:53 PM 1/8/03 -0800, Brett Calhoun wrote:
>All,
>
>I believe formal comments should go to the SCVURPPP Chair. How do the
co-permittees know what the time frame is for comments or a revision?
>
>Comment 5. Large woody debris is addressed as a "permit" requirement in
>the recently submitted Rural Public Works Guidance Manual and
>Performance Standards.
>
>I don't believe the San Mateo side which includes the vast majority of
>the watershed has a permit requirement to submit a management plan for
>large woody debris, and that is really a formal topic between the
>SFRWQCB and the San Mateo municipalities.
>
>
>J. Brett Calhoun
>
>Senior Water Quality Specialist
>
>Santa Clara Valley Water District
>
>408 265-2607 ext.2653
>
>jcalhoun@scvwd.dst.ca.us
>
><?xml:namespace prefix = o ns =
>"urn:schemas-microsoft-com:office:office" />
>>-----Original Message-----
>>From: Laura Young
>>Sent: Wednesday, January 08, 2003 4:20 PM
>>To: 'Adam W. Olivieri'; Beau Goldie; Roger Narsim; Brett Calhoun
>>Cc: 'Phil Bobel (E-mail)'; 'Steve Homan'; Jennie Micko; Patricia
>Showalter; Dipankar Sen
>>Subject: Reg Bd review and comment SF Creek workplan submittals
>>Importance: High
>>

>>RE- submittal for provision 9(f)(ii)
>>
>>I received comments from Regional Board (Jan O'Hara and Sandi Potter)
>>on the Revised workplan submittal of the San Francisquito Creek
>>Watershed Assessment of Sediment Management Practices - Plan and
>Schedule, October 15, 2002. Jan provided me informal, hand written
>>comments yesterday
>>(1/7/03) after BASMAA Monitoring meeting, and we met to discuss and go
>>over them.
>>
>>Adam/Beau - Is this OK or does the Program need official comment
>>letter from Regional Board?
>>
>>See my responses below. No date was discussed for this second revison.
>>
>>Regional Board comments as follows:
>>1. We like the tables and encourage more use of tables.
>>LCY - I will put District actions in table format.
>>
>>2. The SCVWD portion doesn't talk about what the District is doing
>>(concrete). The text is vague or discusses grants rather than
>>actions. See the table of specific actions: HMP, 83-2 Water Resources
>>Protection Ordinance, Limiting Factors Analysis LCY - I will state
>>that bank stabilization, erosion control, and sediment removal occur
>>as problems arise, and include history of District activity in
>>watershed, last 5 years (?) - I'll check again with Jennie Micko's
>>group. I will add HMP, 83-2, Limiting Factors Analysis - also
>>watershed group's long-term assessment for flood control project.
>>
>>3. We support parties working together to obtain the info needed for
>>the
>>TMDL: HMP, Limiting Factors study, JPA's SF Creek Watershed
>>Assessment. The work plan should relect this.
>>LCY - Alot of this, stakeholders working together, was in the other
>workplan for the Sediment Assessment, but will also include in this one.
>>
>>4. The schedule seems good through 9/1/04, but completion dates for
>>implementaion must be moved up from 9/1/08 to 9/1/06, with monitoring
>>to determine the effectiveness of implementation. LCY - I don't know
>>how to estimate completion dates for implementation when we don't know
>>what all we're implementing yet. Can we complete implementation in 3
>>years? What about HMP and 83-2 - does District have an implementation
>>schedule for these? Effectivness monitoring can be coordinated with
>>monitoring for District's/COE long-term assessment for flood control
>>project.
>>
>>5. Per the permit, actions/planning must include management of large
>>woody debris and live vegetation. LCY - This will be evaluated by the
>>consultants in implementing this workplan, but I will make it more
>>clear.
>>
>>6. The SCVWD portion of the work plan doesn't speak to the need for
>>habitat. LCY - This will be done by including the Limitng Factors
>>Analysis, HMP, 83-2, CIP actions in items 2 and 3 above. I will
>>include more text on habitat.
>>
>>ALSO RE- submittal for provision 9(f)(i)
>>Jan hasn't reviewed the other workplan San Francisquito Creek
>>Watershed Sediment Assessment Workplan, August 31, 2001. She
>>apologized for that. Since I'm revising it to be in line with the
>>consultant's scope and schedule from prop 13 grant, and changes to
>>USGS work, she will now wait and review the revised version.
>>
>
>>Laura Young
>>Santa Clara Valley Water District
>>408-265-2607 x2461

>>
>>##
>>
>>This message has been scanned by F-Secure Anti-Virus for Microsoft
>>Exchange. For more information, connect to http://www.F-Secure.com/

Adam W. Olivieri Dr.PH, P.E.
EOA
1410 Jackson St.
Oakland, CA 94612

510-832-2852

SECTION 1. INTRODUCTION

This workplan is submitted in fulfillment of the Santa Clara Valley Urban Runoff Pollution Prevention Program (SCVURPPP) NPDES permit Provision 9(f)(*i*) and the San Mateo County-wide Stormwater Pollution Prevention Program (SM-STOPPP) provision C.10. The SCVURPPP and SM-STOPPP permit provisions requires the Programs to submit a workplan to the Regional Board regarding to conduct a watershed analysis of San Francisquito Creek.

This workplan responds to the following required permit provision items (9(f)(*i*) 1,2,3 and 4):
1. Quantitative characterization of sediment and water inputs to the creek;
2. Relative roles of sediment associated with natural and anthropogenic land use discharges;
2. Sediment conveyance from headwaters to the Bay; and
3. Development of a rapid sediment budget.

In this workplan, the key tasks are identified on a planning level as they relate to assessing the sediment impairment in the watershed and its impact to flood control and sensitive species populations, and identifying appropriate watershed management measures. The workplan outlines the goals, objectives, and approaches that the Programs and its co-permittees will use to assess sediment impairment in the San Francisquito Creek watershed. This effort will also support a holistic approach to watershed management in the development and implementation of the most practicable erosion control and sediment management measures.

Overview of Watershed Processes

The development of the sediment assessment and analysis requires a comprehensive understanding of the complex, interwoven physical and ecological processes that are occurring in the watershed. This section briefly describes these processes and their importance in determining sediment impacts.

Sedimentation and Watershed Processes

Sedimentation is a function of complex, interrelated watershed processes such as infiltration of rainfall, soil erosion, channel morphology, and riparian habitat. These affect of these processes on sedimentation are increased due to anthropogenic causes such as agriculture, timber harvesting, livestock and ranching, urbanization, residential development, road development, recreation, and water resources operations. Anthropogenic impacts result in increased erosion and sedimentation beyond the natural occurring processes, resulting in impairment of the aquatic habitat and biological resources, and an increase in flood events and severity due to reduction in flood channel conveyance.

Rainfall infiltration is affected by watershed geology and soil type, geography and slope, soil saturation, and vegetation density and type (e.g. forest, grassland). Natural and anthropogenic events also influence infiltration such as ground disturbance from fire, timber harvesting and forestry practices, grading for construction, urban and rural residential development, mining, and agriculture. Impervious surfaces, such as urban areas and roads, decreases rainfall infiltration and cause increases in stormwater runoff into creeks, producing an increase in peak stormwater volumes and potential to increase flooding. In addition, the increased stormwater runoff results in a potential increase in stream channel scour, contributing to a loss of riparian corridor and aquatic habitat, and potential property damage. The decrease in infiltration, increase in channel scour, and degradation of the stream channel results in the drawdown of the water table and potential loss of summer groundwater flows.

The causes and degree of soil erosion is affected by watershed soil type and geologic conditions, steepness of slopes and slope length, vegetation density and cover, and ground disturbance. Increased erosion often occurs due to the disturbance and changes in vegetation density and cover from timber harvest operations, hillside agriculture, urban development and fire. Ground disturbance from roads and highways, urban development, construction, mining, grazing, and recreation can all cause permanent impacts that increase soil erosion. Erosion is also caused by the release of concentrated stormflows from road culverts, stormdrains, and runoff from impervious surfaces.

The development of roads and highways also contributes to increased erosion and sedimentation in the watershed. Roads act to increase surface runoff by intercepting groundwater in the infiltration process and redirecting it along the road to stormdrains that empty to the stream channel. Increased erosion also occurs from road surfaces, ditches, culverts and road cuts. In addition, roads cut into hillsides increase the potential for mass wasting and landslides.

Soil erosion is also a factor of the amount of upland and riparian vegetation that is present. Soil erodes from slopes when protective vegetation is removed, or is not dense enough to protect soil from the impact of rainfall. Riparian vegetation serves to stabilize the stream bank, as well as providing shade, cover, and forage areas for aquatic life. While bank erosion may contribute to the removal of mature, riparian trees, this process creates large woody debris (LWD) in the stream channel, which serves as a critical element of fish habitat. All riparian vegetation, as well as aquatic biota, requires the availability of summer groundwater, which may be lost through channel degradation and the lowering of the water table.

The increase in soil erosion results in the impairment of water quality and aquatic habitat, filling-in of creek channels and a potential increase in flooding. The filling of creek channels further promotes bank erosion, resulting in the loss of riparian habitats and potential property damage. Increased sedimentation rates have contributed to the filling of Searsville Lake resulting in the loss of its water storage capacity and contributing to flooding of areas upstream of the lake.

Channel Form and Function

Channel confinement influences the affect of increased sedimentation and the impacts to watershed processes. Channel morphology is classified as confined or unconfined channel, and depicts the form and function of the stream channel to transport sediment, convey floodwaters, and provide aquatic habitat. Confined channels, such as those found in the headwaters of the upper watershed, are typically bound by bedrock with canyon-like formation and high slope. These channels serve to transport large amounts of sediment, but do not store much sediment. Conversely, unconfined channels such as San Francisquito creek and tributaries meander through the alluvium of the lower watershed, where flood flows fill the bankfull channel and spill out onto the adjacent floodplain. The San Francisquito Creek floodplain is highly urbanized, restricting the creek's ability to naturally change and meander.

Natural channel features typically consist of gravel bars, riffles and pools and a floodplain with riparian plants. These complex channel features create suitable habitat for aquatic biota. The bars, riffles and pools also reflect the natural processes of scour and deposition that occur during a storm event or flood. During periods of high flow, the channel transports large gravel and sediment, while fines are deposited on the floodplain or slack water areas. Natural channel flow is unsteady and varies with inputs from tributaries, changes in slope, channel size and shape, obstructions in the channel, and diversions. Channel modifications and floodplain development affect natural sedimentation processes and flood conveyance. Removal of vegetation from the stream channel increases flow velocity and channel erosion, which in turn results in channel incision, the loss of natural bed forms (riffles, bars, pools, and riparian vegetation), and the loss of summer groundwater needed for cool water pools. Therefore, highly modified urbanized streams may not be capable of naturally supporting reproduction and growth of riparian and aquatic species at historical levels. Channel modifications and urbanization also contribute to an increase in fine sediment from higher erosion rates in the watershed.

Natural sedimentation processes are also impacted by reservoir and water diversion operations. Reservoirs retain sediment and often increase channel scour below the dam, causing changes in aquatic and riparian habitat and lower groundwater levels. Reservoir releases in the summer months create warm water habitat conditions downstream. Creek incision and braiding results from low flows due to water diversions, and increases the number of barriers to fish passage. Excessive groundwater pumping lowers groundwater levels, resulting in the loss of summer flows and pools, and causing riparian vegetation to die. In addition, reservoir releases may attract migrating fish into the stream before tributaries have adequate flow to support spawning.

An impact of urban and residential development is the increase of impervious surfaces, which results in the increase of pollutant runoff in stormwater, the rapid flow and evacuation of storm runoff, and decrease in recharge to the groundwater aquifer. Urban stormwater runoff carries excessive soil, leaf litter, organic debris, as well as other contaminants into creeks. Runoff adversely affecting the natural flow hydrograph by producing peaked flows of short duration, a result of concentrated flows due to limited storage and high volume pulses. This also results in increased erosion, and impacts the aquatic habitat by increasing inputs of nutrients and pesticides, that are toxic to aquatic species and reduce the food source for aquatic wildlife. Invasive plant species are also carried to streams or eroded from banks. Summer runoff from lawn and garden irrigation also contributes to warm water inputs to the creek.

Steelhead Trout Life Cycle and Habitat Requirements

One of the aquatic species of concern in the San Francisco Creek watershed is the steelhead trout, with spawning populations found in San Francisco Creek and its tributaries. Steelhead trout require streams of high water quality with low siltation, and that possess a complex habitat structure consisting of large wood debris, gravel pools and riffles, riparian shade, and cold summer groundwater. Steelhead trout habitat is created and sustained through the natural watershed and channel processes discussed above. Rainfall infiltration in winter sustains the cool groundwater flows for summer rearing habitat. Vegetated upland and riparian areas sustain low erosion rates in the watershed to create high water quality and low sediment in spawning gravel. Natural channel processes create the complex channel bed forms of gravel bars, riffles and pools and riparian cover required for fish habitat throughout the steelhead life cycle. The presence of cold water habitat reduces the number of warm water predator fish.

Steelhead require specific habitat conditions for successful development through the various life cycle stages of adult migration, spawning, egg incubation, emergence of fry, rearing of juveniles, and out migration of smolts. These habitat requirements include streams that lack excessive channel scour and siltation of gravel beds and pools, with cold water temperatures high in dissolved oxygen. The stream channels must be barrier-free and have adequate streamflow for migration, spawning, incubation and rearing. Steelhead streams must be low in turbidity and high water quality. Steelhead require clean, well-aerated, silt-free spawning gravel, as well as complex habitat of pools and riffles, riparian vegetation, and large woody debris, providing areas suitable for refuge, rearing, resting, and forage. This complex habitat structure also supports macroinvertebrate populations and provides food production areas. Young fry, juveniles, and migrating smolts also require low populations of warm-water predators, which are often found in lakes and reservoirs, artificial ponds, or streams predominated by warm water temperatures.

The early life stages of steelhead trout are very susceptible to excess sediment. Steelhead build their redds in the gravel of the stream bottom. The eggs, buried one to three feet deep in the gravel redd, rely on a steady flow of clean, cold water to bring oxygen and remove waste products. The eggs hatch into alevin and later emerge to the stream as fry through the interstitial spaces in the gravel. During this period, any sediment deposition and shifts in the gravel bottom can cause mortality.

The redd is formed as a depression in the streambed creating currents that draw water down into the gravel. Suspended sediment in the water column is sucked down into the redd, settling in the interstitial spaces of the gravel, suffocating eggs, alevin, and fry. In addition, high turbidity also impacts the feeding ability of juvenile steelhead. Steelhead juveniles seek refuge in the interstitial spaces of gravel, cobbles and boulders to avoid predation. The gravel of the streambed is also important for aquatic invertebrates, which supply most of the food for steelhead. As fine sediment covers the streambed and clogs interstitial spaces of the streambed gravel, impacting juvenile steelhead refuge and forage areas.

San Francisquito Creek possesses one of the few remaining steelhead trout populations remaining in the San Francisco Bay area. Adult steelhead enter the mouth of SF Creek, migrating upstream to spawning habitat located on Los Trancos Creek and Bear Gulch Creek tributaries. Currently, the upper watershed of Corte Madera Creek and Sausal Creek, is cut-off from fish passage by the Searsville Lake dam, however, this area is reported to support a landlocked steelhead population.

Potential factors affecting steelhead trout habitat

Adult steelhead migration may be impacted by false flows from urban runoff or reservoir release. Other factors impacting steelhead habitat include soil erosion, barriers to passage, channelization, incision and braiding of stream channel, reduced flows from water diversions, and loss of complex habitat in creek. Potential impacts to steelhead spawning include soil erosion, siltation of creek spawning areas, and impaction of spawning gravel. Spawning habitat is also impacted by the loss of habitat complexity due to channelization and lack or riparian vegetation and large woody debris. Other impacts to spawning areas include the loss of gravel due to degradation, channel incision, and reservoir and watershed changes. Spawning areas are also affected by the increased peak storm runoff due to urban development resulting in channel scour.

Adverse impacts to steelhead egg incubation, emergence, and juvenile rearing include reduction in flows from excessive surface water and groundwater diversions, and the loss of the natural channel form and function due to channelization and changing flow patterns. The removal of riparian cover and large woody debris, soil erosion and siltation of creek channel, excessive channel scour or filling also affect early life stages. Excessive water temperatures, and warm water releases from lakes, reservoirs, and urban runoff adversely affect incubation, emergence and rearing. Potential impacts to steelhead smoltification and smolt migration include increased numbers of warmwater predator fish, low flows due to water diversions, and loss of channel form and habitat. Smolt migration is impacted from barriers to fish passage such as channel braiding from low flows and deposition of sediments, loss of guiding river currents due to reservoir or ponds, and excessive water temperatures.

Regulatory Background

The proposed project presented in this work plan will assist the co-permittees of the Santa Clara Valley Urban Runoff Program (SCVURPPP) and the San Mateo Countywide Stormwater Pollution Prevention Program (SM-STOPPP) to comply with the sediment assessment and control provisions in their storm water NPDES permits, as well as provide data to support the Regional Board with development of the sediment TMDL.

Provision 9(f)(*i*) of the Santa Clara Valley Urban Runoff Pollution Prevention Program NPDES Permit Order No. 01-024 reads as follows:

> "**San Francisquito Creek.** Submit a plan and time schedule for implementation acceptable to the Executive Officer by September 1, 2001 to conduct a watershed

> analysis of San Francisquito Creek in cooperation with the San Mateo Countywide Stormwater Pollution Prevention Program (STOPPP). The plan will provide for: (1) quantitative characterization of sediment and water inputs to the creek; (2) relative roles of sediment associated with natural and anthropogenic land use discharges; (3) sediment conveyance from headwaters to the Bay, and (4) development of a rapid sediment budget."

Provision C.10 of the reissued San Mateo Countywide Stormwater Pollution Prevention Program NPDES Permit Order 99-059 reads as follows:

> "**Watershed Management Initiative for San Francisquito Creek:** East Palo Alto, Menlo Park, Woodside, Portola Valley, and the County of San Mateo ("Municipalities") shall develop and implement an erosion control and prevention plan and diazinon toxicity reduction plan. A draft scope of work and outline for the report(s) shall be submitted by September 1, 2000. Interim draft report(s) shall be submitted by March 1, 2001, and final report(s) shall be submitted by September 1, 2001. The final report(s) shall include a schedule for implementation of the plan(s). In addition to, and to facilitate the development of the reports specified above, the dischargers shall coordinate with and participate in the development of the watershed assessment and management plan for San Francisquito Creek watershed and the Santa Clara basin that is being developed through the Santa Clara Basin Watershed Management Initiative."

The SM-STOPPP Municipalities have been further instructed by staff of the Regional Board to prepare a sediment budget for the entire watershed (San Mateo County and Santa Clara County inclusive) to identify the causes and sources of sedimentation impacting San Francisquito Creek.

In an effort to facilitate coordination between the two Programs, the Regional Board was requested to resolve the different requirements and schedules for compliance between SM-STOPPP and SCVURPPP regarding the sediment assessment and control measures plans for San Francisquito Creek. In comments from the Executive Officer of the Regional Board (dated November 13, 2000 File No. 2178.07 (MBN)) in response to the SM-STOPPP submittal *Draft Scope of Work and Report Outline for Erosion Control and Prevention Plan* of August 30, 2000, the Regional Board addressed the disparity in the permit conditions and extended the submittal dates for SM-STOPPP in order to align the permit requirements of the two Programs.

To this end, the co-permittees for the SCVURPPP and SM-STOPPP, along with other agencies and organizations in the watershed, are actively participating in a stakeholder process and are working in cooperation and coordination in development of a holistic, watershed approach of sediment assessment and analysis to determine sediment loadings and impacts in the watershed, and the characterization of management practices to reduce sediment impairments. As directed by the Regional Board, SCVURPPP and SM-STOPPP have used the time period from September 1, 2000 to September 1, 2001 for planning and coordination, problem identification, defining goals and objectives, and the coordination of ongoing efforts within the watershed. In addition, the stakeholders were successful in the award of a Proposition 13 Phase I grant (Prop 13 Grant Project) for watershed sediment analysis and development of a sediment reduction plan.

At the direction of Regional Board staff in June 2001, the co-permittees of the two programs were directed to halt further development of the sediment assessment workplan in order to direct their efforts to the initiation of the Prop 13 Grant project and development of the grant project's scope of work by a technical advisory committee. The Regional Board informed the stakeholders, that the Prop 13 grant proposal was sufficient to comply with the permit provisions, and satisfied the submittal requirements for the watershed sediment analysis (due September 1, 2001) and the assessment of management practices work plans (due March 2002). However, upon receipt of a letter from the Regional Board dated July 25, 2001, the Regional Board stated that it is not obligated to follow the changes to the permit requirements or guidance they provided in the previous communication, and furthermore, the co-permittees of the two programs were required to submit work plans as originally specified in their NPDES permits. This resulted in a drastically shortened preparation, comment, and review period for this sediment assessment work plan and the Erosion Control and Prevention Plan submittal by SM-STOPPP.

A large portion of the work as presented in the draft 2001 work plan submittal was contingent on the Prop 13 Grant Project scope of work, which had yet to be developed. During the 2002 period, the Technical Advisory Committee worked with the JPA in developing the scope and grant contract language with the SWRCB. The Prop 13 grant contract was recently completed between the JPA and SWRCB in January 2003. As anticipated, details of certain tasks, their implementation, and schedule as presented in the draft 2001 work plan required revision to reflect the scope and completion of the Prop 13 Grant Project. The co-permittees have followed adaptive management in the revision and implementation of this work plan in order to incorporate the following Prop 13 Grant Project scope of work and schedule. This matter is addressed further in the following section *Proposition 13 Grant Funding.*

In addition, due to federal budget constraints, the scope of the USGS Include overland transport/land use change modeling project was greatly reduced and schedule delayed. As a result, certain tasks of this project involving integration and support of the USGS modeling effort have been revised.

This workplan does not include the scope of *Erosion Control and Prevention Plan* submittal by SM-STOPPP on September 1, 2001 and the *Assessment of Management Practices* submittal by SCVURPPP on March 1, 2002 (SCVURPPP Permit Provision 9 (f)(ii)). This element of the project will be addressed under the two separate submittals.

In order to comply with their respective NPDES Permit conditions, the SCVURPPP and SM-STOPPP co-permittees propose a comprehensive study of sedimentation issues impacting the San Francisquito Creek watershed, and will also utilize sediment analyses underway in the watershed by the U.S. Geological Survey (USGS) and Stanford University. The study is anticipated to produce information that will also assist the Regional Board in preparing a sediment Total Maximum Daily Load (TMDL) for the watershed.

The basic components of a watershed sediment assessment and analysis include a problem statement, quantitative characterization of sediment and hydrologic inputs, source identification, sediment loadings analysis and land use contributions, sediment transport, characterization of channel and habitat condition, and potential management options. The watershed sediment assessment and analysis will require an integrated approach involving all of the jurisdictions, resource agencies and the community who have an interest in its outcome. A work group comprising representatives of the County of San Mateo, County of Santa Clara, USGS, Stanford University, Santa Clara Valley Water District, San Mateo County Stormwater Pollution Prevention Program (SM-STOPPP), Santa Clara Valley Urban Runoff Pollution Prevention Program (SCVURPPP), JPA, and the San Francisquito Creek Watershed Council (formerly CRMP) has been formed to address the watershed assessment.

The Regional Board stated in a letter addressed to the SM-STOPPP Coordinator July 18, 2000, "Erosion control activities recommended as a result of the plan must be conducted within the holistic context of flood management, stream-riparian habitat protection and restoration, and streamside property protection." The municipalities are committed to complying with the intent of the Provision, i.e. the continuing beneficial uses of San Francisquito Creek and the implementation of improvements for the purposes of fish and wildlife habitat, streambank stability and flood control. The recently created San Francisquito Creek Joint Powers Authority (JPA) exemplifies this commitment and may become the agency to continue coordination of efforts related to this work plan. Member entities of the JPA include the cities of Menlo Park, Palo Alto, East Palo Alto, the Santa Clara Valley Water District and San Mateo County Flood Control District. Stanford University and SF Creek Watershed Council are Associate Members (non-voting) of the JPA. The JPA's purpose is to: manage the joint contribution of services and provide policy direction on issues of mutual concern relating to the San Francisquito Creek, including bank stabilization, channel clearing and other Creek maintenance, planning of flood control measures, preserving and enhancing environmental values and instream uses, emergency response coordination, and to make recommendations to member entities for funding and alternatives for long term flood control.

The stakeholders also propose the watershed assessment will include WMI coordination, and coordination and support with the U.S. Geological Survey for watershed modeling, GIS mapping, data base compilation and the INCLUDE project information synthesis.

Proposition 13 Grant Funding

On May 17 2001, the State Water Resources Control Board approved Proposition 13 Phase I Grant funding of $200,000 for the *San Francisquito Creek Watershed Analysis and Sediment Reduction Plan* project. The Proposition 13 grant application was completed and submitted to the SWRCB by the San Francisquito Creek JPA, which will administer the grant contract with the SWRCB. Following the award of the grant during the period from May 2001 to January 2003, JPA staff negotiated the contract terms with the State and the development of a preliminary scope. It was originally expected that the funds would be available late 2001; however, the contract process was not completed until January 2003. The grant project received an early start date from the Regional Board in October 2002. The proposed Prop 13 project is philosophically consistent with the intent and goals of the NPDES permit provisions, and contain many of the same elements as presented in this work plan.

The Proposition 13 Grant funding will support a majority of the stakeholders' proposed activities in this work plan that are not undertaken by ongoing or planned studies by USGS, Stanford University, or other stakeholder groups. The *San Francisquito Creek Watershed Analysis and Sediment Reduction Plan* project will support a holistic watershed approach undertaken to address impacts from sedimentation on steelhead fisheries, aquatic habitat, and flood conveyance, as well as other beneficial uses designated for San Francisquito Creek. The goals of the proposed Prop 13 project are to conduct a specific sediment analysis of the watershed that will be used to develop a sediment reduction plan, which will prioritize erosion control and sediment reduction measures to be implemented throughout the watershed. A rapid sediment budget analysis will be conducted that will identify and quantify key sources of sediment loadings and land use contributions in the San Francisquito Creek watershed. In addition, historical and existing condition analysis for sediment will be conducted based on available data and records. The sediment reduction plan will be developed based on an assessment of existing management practices, and evaluation and recommendations for additional erosion control measures to be implemented. Note: This workplan does not include the scope of the Assessment of Management Measures and Sediment Reduction Plan to be developed under Prop 13 Grant Project Task 6 and 7. This element of the project is addressed in the Erosion Control and Prevention Plan submittal by SM-STOPPP on September 1, 2001 and the Assessment of Management Practices submittal by SCVURPPP on March 1, 2002.

A requirement on the Proposition 13 grant project calls for the formation of a Technical Advisory Committee (TAC), whose role in the Prop 13 process is to provide guidance in plan development and review consultant products and deliverables during implementation of the grant project. A TAC was established by the stakeholders in September 2001. The TAC is viewed as a group of 5-6 scientist with expertise in geology and river morphology, sediment impacts and erosion control, fisheries biology, as well as knowledgeable of the San Francisquito Creek watershed and familiar with the Rapid Sediment budget Analysis process. The TAC will convene to review the Rapid Sediment Budget Analysis scope, consultant proposals submitted in response to a Prop 13 project RFP, assist in the consultant interview process, and provide peer review of work products. Another level of the TAC will be those knowledgeable of work completed within the watershed and history of events. These folks will act as a general knowledge resource and as reviewers of the work products to guarantee completeness of the assessment effort and prevent duplication of work. This will promote efficiency and effectiveness through out the assessment process, and prevent wasting limited resources.

Problem Identification

The primary issues of concern driving development of a sediment assessment for the SF Creek watershed are 1) the potential degradation of steelhead spawning habitat from siltation; and 2) increased flooding for which streambed aggradation from sedimentation may be a contributing factor.

The San Francisquito Creek Watershed consists of both natural and urbanized stream systems. The sediment assessment requires incorporation of the analysis and assessment of hydrologic and geomorphologic characteristics of stream channel, analysis of reservoir sedimentation processes and management issues, identification of aquatic species and habitat requirements, and potential factors affecting aquatic habitat. The sediment assessment analysis will identify and quantify the potential impacts from sedimentation and contributions due to land use, as well as identifying and quantifying changes resulting from management and land use scenarios.

Understanding of sedimentation issues and impact on aquatic habitat and flooding requires an associated understanding of the physical and ecological processes, as previously discussed, and knowledge of the watershed. The sediment assessment will incorporate the many completed, ongoing, or planned investigations and studies in the watershed involving water quality and biological monitoring, and hydrologic and geomorphological investigations in the San Francisquito watershed, and coordinate with stakeholders to develop a discussion and consensus building forum.

TMDL Development Requirement

San Francisquito Creek has been listed as impaired by sedimentation under Section 303(d) of the Clean Water Act. The two major issues of concern in development of a sediment TMDL for the San Francisquito Creek watershed are increased flooding and degradation of fisheries and aquatic habitat. The sediment assessment to be conducted will support the TMDL in part, to determine whether channel sedimentation is causing significant adverse impacts to existing and potential habitat for native cold-water fisheries and endangered aquatic species, and to impact flood channel conveyance. The sediment assessment will also confirm or reject the validity of the sediment impairment listing, and determine linkages to sources of sediment at the watershed scale.

Project Goals and Objectives

Goal: To identify and quantify sources of sediment loadings and land use contributions, and assess the impact of sedimentation on aquatic habitat and flood flow conveyance. The sediment assessment will be used to develop implementable actions, based on science that will address impacts from sediment on fisheries, aquatic habitats, and flood conveyance, as well as other Regional Water Quality Control Board beneficial uses designated for San Francisquito Creek. In addition, this information can be used by the California Regional Water Quality Control Board, San Francisco Bay Region to guide water quality assessment (305(b)) and impairment (303(d)) decisions.

The watershed sediment assessment and analysis, which includes the development of a rapid sediment budget, will be conducted in order to develop an erosion control and prevention plan. The sediment assessment will assist in the evaluation of appropriate and feasible management practices to be implemented to prevent and reduce excess sediment production to streams, enhance aquatic habitat, and reduce flood hazards.

The project objectives of the watershed sediment assessment are as follows:

- Develop an understanding of how changes in current and historical land use activities affect peak flow runoff and sediment input to streams;
- Determine and quantify flow and sediment conveyance processes through the stream network;
- Identify, analyze, and address adverse impacts of excess sediment production to streams caused by anthropogenic activities;
- Develop an understanding of flow and sediment impacts to life history needs of native aquatic species, and support aquatic habitat enhancement and restoration;
- Promote the recovery of threatened species, such as steelhead trout, which is a priority and primary issue driving the development of the sediment TMDL for SF Creek;
- Improve floodwater conveyance and reduce incidence of flooding and property damage;
- Conduct the sediment assessment and the development of the control measures plan in the holistic context of watershed management and in coordination of the WMI; and
- Utilize a consensus building approach that involves regulatory agencies, community members, stakeholder groups, and scientific experts to find mutual solutions to creek issues.

Data collection and analysis will focus on characterizing channel condition, and habitat condition with respect to factors limiting the populations of aquatic species, especially threatened and/or endangered native aquatic species. Specifically this shall include the following data analysis:

- An evaluation of erosion and channel sedimentation processes and the influence on flood conveyance (e.g., bank erosion intensity, channel geometry, baseflow, fine sedimentation in pools, etc.);
- An evaluation of the balance between stream sediment supply and transport capability and the consequential effects on aquatic habitat attributes (e.g., pool depth, permeability of spawning gravel, streambed and bank stability, etc.); and
- A characterization of physical water quality parameters and habitat structure (e.g., streamflow, temperature, turbidity, riparian canopy, species distribution, etc.) with reference to life history needs of threatened or endangered aquatic species.

The watershed sediment assessment will involve an evaluation of the balance between stream sediment supply and transport capability, and the resulting effects on biologically important, aquatic habitat attributes (e.g. pool depth; permeability of spawning gravels; stream bed and bank stability; streamflow, in-stream temperature, and habitat structure with reference to life history needs of sensitive species). The assessment will also investigate whether other causes for aquatic habitat impairment may exist, which warrant investigation (e.g. baseflow depletion, increases in stream temperature, nutrient pollution, riparian condition, absence of LWD, etc.), and identify linkages to causes at the watershed scale.

This study will attempt to answer the following management questions:

1. What has been the effect of land use change in contributing sediment to the stream channel, and on changes to channel morphology, function, and dynamics?
2. What is the effect of episodic disturbances such as floods, fires, landslides, or earthquakes on runoff, sediment supply, peak flows, and changes in channel form?
3. Is the watershed impaired with regard to sediment?
4. What impact does sediment have on the carrying capacity of the creek and aquatic habitat?
5. What is the effect of anthropogenic alterations to stream channel, flood plain, and estuary form and functions (e.g. levees, channelization, sediment and debris removal, bridges, etc.)?
6. Has San Francisquito Creek responded to Searsville Reservoir construction (e.g. hydrograph, suspended and bedload sediment, channel morphology)?
7. How can the multiple land uses of an urbanized watershed be managed to minimize impacts to the ecological habitat?

SECTION 2. PROJECT BACKGROUND

Watershed Description and History

San Francisquito Creek is the last riparian, unchannelized urban creek on the southern Peninsula of San Francisco Bay. The creek discharges into the South Bay south of the Dumbarton Bridge and north of the Palo Alto Flood Basin. The creek forms boundary between two counties, Santa Clara and San Mateo, and flows through parts of five municipalities (Menlo Park, Palo Alto, East Palo Alto, Portola Valley, and Woodside). Historically, San Francisquito Creek once supported a thriving steelhead trout population in the creek and tributaries, however, today the creek sustains diminishing trout populations. Steelhead is a federally listed special status (threatened) species. Impairment of the freshwater fishery caused San Francisquito Creek to be listed on the 1998 Clean Water Act Section 303(d) list of impaired water bodies due to sedimentation. Sediment deposits that create physical barriers to fish migration or silt-in fish spawning gravel and rearing pools may possibly contribute to this problem in the San Francisquito Creek watershed.

In the spring of 1998, the runoff from a series of heavy winter rains resulted in urban flooding in the lower San Francisquito Creek watershed, causing $28 million dollars in property damage. The unprecedented magnitude of the flood-related damages and the potential threat to human health and safety has prompted investigations into the causes and mechanisms of flooding in this watershed. The focus of these investigations concern issues related to sediment supply (including bank stability and erosion) and deposition (especially pertaining to reductions in flood storage and conveyance capacity). The amount and quality of sediment contributed to the creek is also affected by the percent of impervious coverage within the watershed, which is related to urbanization.

A dam built in 1892 and reservoir, Searsville Lake, is located on the upper San Francisquito Creek mainstem on Stanford University property at the Jasper Ridge Preserve. As the lake approaches the end of its life cycle, it is nearly filled with sediment, and is projected to completely fill with sediment within 2 to 25 years depending on future weather conditions. The filling of the lake with sediment has exacerbated flooding of residences located within the floodplains of tributaries to the lake. The dam is also a barrier to migrating steelhead, unable to reach spawning streams in the upper watershed.

Stanford University is assessing possible management options, such as lowering the dam or possible removal of the dam. Reports indicate that lowering the dam will mitigate flooding of upstream residences. Complete filling of the lake and either lowering or removal of the dam could have severe consequences for communities and stream habitat below the dam. Increased sediment load could reduce the carrying capacity of the stream leading to more frequent and severe flooding and increased degradation of aquatic habitat. The Searsville Lake Impact Study was commissioned by Stanford University (2001) to evaluate the impact of lowering or removal of the dam on flood conveyance and aquatic habitat downstream of the dam.

Landscape change caused by timber harvesting, agricultural practices, grazing, road building, land use changes, and natural climate variability have varied the annual watershed sediment yield, transport, and deposition in Searsville Lake. Sediment deposits at the mouth of the creek provide a long-term record of sediment transport in the creek, reflecting land use change. The deltaic deposits into San Francisco Bay provide an historic record toward establishment of baseline conditions for the natural system prior to building the dam and modification of the watershed by non-native peoples.

Stakeholder Background and Agency Coordination

This project is being conducted in conjunction with the Santa Clara Basin Watershed Management Initiative (SCBWMI), and within a coordinated, stakeholder process of representatives from federal, state, and local governments, environmental and academic groups. The following table presents a list of participating stakeholders in the San Francisquito Creeks Sediment Assessment Project

Table 1. List of Participating Stakeholders

San Mateo Countywide Stormwater Pollution Prevention Program (SM-STOPPP)	Santa Clara Valley Urban Runoff Pollution Prevention Program (SCVURPPP)
County of Santa Clara	County of San Mateo
East Palo Alto	City of Palo Alto
City of Menlo Park	City of Portola Valley
City of Woodside	Stanford University
US Geologic Survey	San Francisquito Creek Joint Powers Authority (JPA)
Santa Clara Valley Water District	Regional Water Quality Control Board, San Francisco Bay Region
San Francisquito Creek Watershed Council	CLEAN South Bay

Interagency Cooperation

The co-permittees of the SCVURPPP and the STOPPP have coordinated efforts and determined cost-sharing agreements and resource allocations among themselves. The US Geological Survey and Stanford University are also providing resources and in-kind services through coordination of studies and investigations undertaken in the watershed and sharing of technical expertise. More information on the USGS INCLUDE project and Stanford University watershed investigations are provided in Section 3 Current Watershed Management Activities.

Watershed Management Initiative (WMI)

The Santa Clara Basin Watershed Management Initiative is a broad, consensus-based stakeholder process made-up of representatives of government agencies, business, agricultural, and industry associations, environmental and civic groups. The purpose of the WMI is to develop and implement a comprehensive watershed management program for the Santa Clara Basin that balances the objectives of water supply management, habitat protection, flood management, and land use to protect and enhance water quality.

The Stakeholder Work Group, *Sediment Observations in Lotic Systems* (SOILS), was established within the SCBWMI as a forum to address the San Francisquito Creek watershed sediment assessment and analysis project and coordinate with the WMI, communicate among groups and decision makers, explore issues and submit technical information.

Environmental Stakeholders

San Francisquito Creek Watershed Council is formerly the Coordinated Resources Management and Planning (CRMP) agency for the watershed, and promotes a diverse and healthy watershed that is valued as a natural and community resource. The Watershed Council has produced a draft watershed management plan, a flood protection reconnaissance investigation, and the Long-Term Monitoring and Assessment Plan (LTMP). The Watershed Council was instrumental in establishing continuous water quality monitoring stations on the creek.

CLEAN Southbay works with stakeholders and citizens to protect the South Bay and its tributary creeks and watersheds from toxic pollution, to protect wetlands and streamside riparian habitat, and to help plan and implement the Santa Clara Basin Watershed Management Initiative.

San Francisquito Creek Joint Powers Authority (JPA)

The San Francisquito Creek Joint Powers Authority (JPA) is comprised of representatives from the City of Menlo Park, City of Palo Alto, City of East Palo Alto, the Santa Clara Valley Water District, and the San Mateo County Flood Control District. Associate members of the JPA include the Watershed Council and Stanford University. The JPA was formed in May 1999 to make decisions that pertain to flood control management of the creek.

Regulatory Agencies

Representatives from State regulatory and resource agencies serve in decision-making, guidance, funding and oversight capacity include San Francisco Bay Regional Water Quality control Board and California State Water Resources Board. The stakeholder processes also works to ensure decision-maker support through regular communication, coordination and participation.

SECTION 3. CURRENT WATERSHED STUDIES AND ACTIVITIES

Data Base Compilation/Coordination

Many watershed studies and management activities have historically taken place or are ongoing by the stakeholder agencies and municipalities. It is anticipated that these studies and activities will provide a major source of existing data to the assessment team, including maps, aerial photos, land management policies and programs, access agreements, and results of field investigations.

Agency coordination and data compilation will support many of the project elements, such as sedimentation history analysis, fish and wildlife habitat research and evaluation, and economic analysis of management options (including flood hazard analysis, risk analysis and cost/benefit analysis). In addition, data integration will be facilitated through coordination with the SCBWMI and utilization of the Interim Data Repository. Further assessment strategies and actions will be developed and considered by the assessment team following completion of the WMI Pilot Watershed Assessment for San Francisquito Creek.

USGS INCLUDE Project

The watershed sediment assessment will be conducted in cooperation and coordination with the USGS INCLUDE project. INCLUDE (Integrated-science and Community-based Values in Land Use Decision-making) is a participatory educational and decision support process and activity, which facilitates interaction among private and public sector decision-makers, stakeholders, and scientific experts. The process applies scientific research information to complex land-use problems in order to clarify the variables and uncertainties with alternative policy scenarios and mitigate conflict among competing interests. INCLUDE integrates the scientific and economic factors, along with social and cultural values into a collaborative problem-solving framework to help achieve balanced solutions to land-use issues.

INCLUDE will also provide a team of experts to synthesis, translate, and communicate data and information into forms available for policy analysis, communicated effectively to decision-makers, and understandable to other scientists and the general public. The USGS collaborators will work with project stakeholders to promote community outreach, education, and awareness, through web development, GIS development, information kiosks, student and school programs, and games and simulations development. The community-based, interdisciplinary and collaborative problem solving approach, tools, techniques and methodology developed in partnership with the San Francisquito Creek stakeholders will be transferred to other watersheds in the region and across the nation.

Current Efforts and Resources

There are many past and ongoing projects and studies within the SF Creek watershed in which the sediment assessment will utilize for sources of information and data. The following is a list of a few of the most notable efforts and resources within the SF Creek watershed:

- *Searsville Lake Sediment Impact Study*, Stanford University, June 2001
- *Pilot Watershed Assessment*, WMI, May 2003
- *San Francisquito Creek Bank Stabilization and Revegetation Master Plan*, JPA, May 2000
- *Portola Valley Creekside Corridor Committee Report*, Town of Portola Valley, Summer 2000

The Searsville Lake Sediment Impact Study involved the following activities: hydraulic model development by the Santa Clara Valley Water District and **nhc**/Balance Hydrologics; a field survey and geomorphological survey conducted of SF Creek from Searsville Dam to the bay; and incorporation of data into HEC-RAS model to evaluate sediment transport in lower SF Creek. This information was used to assess sediment dynamics and storage between the dam and lower San Francisquito Creek. **nhc** used the HEC-RAS model database to develop a mobile bed HEC-6 model of the creek. The HEC-6 model was used to assess the sedimentation transport and depositional characteristics of the creek due to a range of sediment inflow scenarios such as filling of Searsville Lake or lowering of the dam. The HEC-6 model is able to simulate the transport and deposition of mixed grain size sediments, and assess downstream fining and depositional characteristics. These characteristics are used to reflect bed and morphological changes and assess changes in flood hazard due to aggradation of the streambed and changes in the stage-discharge rating curve. HEC-RAS and HEC-6 can also evaluate tidal influence, and channel and bridge contractions.

In addition to work completed for the Searsville study, previous geomorphic assessments of SF Creek watershed have been conducted by Stanford University, USGS, SCVWD, JPA, **nhc**, Balance Hydrologics, and other stream scientists. This information will be used to assess sediment sources to SF Creek including loadings contributions from Los Trancos and West Bear watersheds. In addition, it is anticipated that a review of these past and current studies will provide preliminary information on changes in channel geometry, bed material and evidence of scour, bed and bank stability, woody vegetation effects on flow, sediment transport, and scour.

The project will require a comprehensive understanding of flood issues and capitol improvement and maintenance activities in the San Francisquito Creek watershed. Historical FEMA Flood Hazard studies, as well as municipal and county flood control engineers, can provide historical channel surveys developed from flood hazard studies, bridge hydraulics or scour assessments, levee maintenance, other channel design activities. This information will be used to provide a comparison of existing channel morphology with historical morphology.

Other Data and Background Information

This project will incorporate historical data and information from watershed hydraulic, sedimentation, and fluvial geomorphology investigations, drainage basin and flow control studies, erosion control and streambank stabilization projects, bridge scour assessments, surface water hydrology, as well as river, estuary and wetland restoration studies. Other sources of data and background information include field monitoring and assessment investigations, watershed mapping, and computer modeling such as hydraulic, sediment transport, and land use modeling.

nhc and Balance Hydrologics, Inc. have completed studies in the San Francisquito Creek watershed involving analysis of hydrologic, sedimentation and geomorphic, and hydraulic processes in the watershed, including the *Family Farm Road Flood and Sediment Control Study* and the *Searsville Lake Sediment Impact Study*. These studies offer analyses and present conclusions developed regarding solutions to flooding issues in the vicinity of Family Farm Road, and analysis of reservoir sedimentation processes and impacts from management scenarios. These studies along with USGS records also provide historical stream gauging data.

SECTION 4. SCOPE OF WORK

Overview of Approach

The following approach will be undertaken by the Assessment Team in order to achieve the goals and objectives of the project:

- Conduct analysis of hydrologic and geomorphologic factors affecting sedimentation dynamics and flooding in the watershed;
- Evaluate hydraulic and ecological consequences;
- Assess impacts to beneficial uses, critical habitat and aquatic species;
- Coordinate with project stakeholders;
- Assess management options to prevent or minimize environmental impacts; and
- Present sediment assessment study and management recommendations.

The following scope characterizes the steps that will be followed in completing the Watershed Sediment Assessment and Analysis Plan, in compliance with the NPDES provisions of the SCVURPPP and STOPPP stormwater programs.

4.1. Task 1 - Gather Existing Data and Information

Compile and review data. All relevant data and information for San Francisquito Creek from headwaters in the upper watershed to the mouth at San Francisco bay will be collected, compiled, reviewed, and analyzed. This includes existing information, studies, data and maps. The Assessment team will identify and review current ongoing studies. All of the compiled data will be reviewed for completeness, quality, and sufficiency.

Define data gaps. Following the review, data gaps will be identified, a list developed of data needs for assessment purposes, and suggested methods for filling data gaps where identified.

Conduct historic conditions analysis. The Assessment Team will evaluate historical conditions (i.e. pre-1900's, depending on available records), which includes obtaining and analyzing historical records and documents, such as old maps, surveyor notes, and photographs. Existing studies include the USGS core study used to determine pre-anthropogenic conditions through analysis of the sedimentation record. The evaluation of historical conditions will draw upon a review and analysis of known relationships on sedimentation and ecology in order to draw conclusions of historical conditions. The researchers will utilize GIS to analyze spatial and temporal changes in hydrogeomorphic conditions and land use in the watershed.

Develop Work Product. A Summary of the data review and list of data gaps will be produced. A technical memorandum of the evaluation of historic conditions will be produced primarily by USGS investigators and in coordination with the Prop 13 contractor (see grant task 4.1).

Funding/Resources. Funding of this task will primarily be through the Prop 13 Grant Task 4 and conducted primarily by participating contractors in coordination with stakeholders, principally SCVWD, CRMP, WMI, USGS INCLUDE, and Stanford University investigations.

4.2. Task 2 – Existing Conditions Analysis

Current and reference state conditions will be defined based on current knowledge and available data, in order to describe watershed process and conditions controlling spatial and temporal variation in stream habitat quality and flood conveyance capacity. The preliminary assessment of historical and current reference conditions will be incorporated into the watershed sediment assessment, modeling scenarios and in-stream habitat assessment.

Review Beneficial Uses. The existing conditions analysis will include a review of watershed beneficial uses as defined by Regional Board and assess the status of water bodies with respect to the beneficial use criteria, such as COLD, RARE, MUN, REC1, and the PFF stakeholder interest.

Define Geographic Scope. The Assessment Team will define the project geographic scope and stream reaches and conduct stream classification, *in coordination with RWQCB studies (e.g. ephemeral streams, blue line, radar surveys)*, for the creek headwaters, tributaries, and mainstem of the watershed. This task involves the preparation of recommendations regarding segmenting streams into reaches for this assessment, based on key physical characteristics, and identifying additional information required to determine changes in channel characteristics. The stream segmentation information will be incorporated into a GIS database and presented graphically.

Define Condition of Aquatic Biological Resources. The existing conditions analysis will include a description and condition of aquatic biological resources, and determination of target species of concern (e.g. special status species such as steelhead and red-legged frog). This task includes a review of existing studies and data on target species of fish, macroinvertebrates and amphibians. This data will be used to define spatial and temporal extent and define condition of aquatic biological resource, and identify gaps in knowledge of aquatic resources. This task will include developing a description of specific habitat and environmental requirements for aquatic and special status species in the San Francisquito Creek watershed. Under guidance from the Regional Board, and with the listing of impairment to cold water habitat beneficial use, steelhead trout is selected as the primary analysis species. Steelhead trout was selected because of its threatened status and declining population in northern California, and the COLD and SPAWN impairment listings for San Francisquito Creek watershed are considered the most sensitive beneficial uses.

Define channel form, function and structure. The current/reference state hydrogeomorphic condition and habitat structure of channel will be defined to subwatershed level, and key salmonid habitat areas and special species habitat areas identified. The existing conditions analysis will include a description of flow regulation and the operations of dams, diversions, reservoirs, and groundwater usage.

Describe land use practices and planning. The existing conditions analysis includes characterizing historic and present day land use practices and planning in the watershed. The management of the riparian corridor will be described, including local government land use and development policy, flood management, stormwater drainage and storm drain outfalls, and control of non-native species. The extent of urban development and residential land use will be determined, and will allow an estimation of percent impervious cover and analysis of its impact.

Conduct existing conditions analysis. The Assessment Team will analyze existing conditions and current watershed processes using existing data, maps and aerial photographs. The data and information gathered in the existing conditions analysis will be used in the development of GIS and spatial data incorporated into data files.

Define reference state sedimentation conditions. Define reference state conditions using current and historic sediment conditions (Task 1). The historical reference model is the assumed watershed condition prior to disturbances caused by European-Americans in mid-1800s (per Regional Board and stakeholder Technical Advisory Committee communications), or as determined based on best available, historical evidence. A preliminary assessment and comparison of current and historic conditions will be used as a basis to define baseline or reference state conditions, in order to evaluate anthropogenic changes in the watershed. Reference areas will be identified as areas possessing low anthropogenic sediment inputs and high habitat values. The post-anthropogenic sedimentation history of the watershed will also incorporate the bathymetric survey and record of deposition of Searsville Lake, utilizing the sediment core analysis by Balance Hydrologics and USGS for the Stanford Searsville Lake Sediment Impact study.

Develop Work Product. A technical memorandum on the existing conditions analysis and reference state sedimentation conditions will be produced. The technical memorandum will include assumptions, analytical approach, and limitation and intended uses of the reference state and baseline conditions.

Funding/Resources. Funding of the Existing Conditions Analysis will primarily be through the Prop 13 Grant Task 4.2 , and conducted primarily by participating contractors in coordination with stakeholders, principally SCVWD, CRMP, WMI, USGS INCLUDE, and Stanford University investigations.

4.3 Task 3 - Conduct Limited In-stream habitat assessment

Review existing data and information. Ecological field data and information will be compiled and evaluated from existing biological studies of the biotic resources of SF Creek watershed. Existing biological studies include an assessment of steelhead habitat in Los Trancos Creek and West Bear Creek watersheds by Dr. Jerry Smith, and the biotic resource summary report for the Stanford University Searsville Lake Sediment Impact Study by H.T. Harvey and Associates (2001). Appropriate measures for evaluating stressors and impairment to aquatic resources will be identified.

Define geographic scope for habitat assessment. The geographic scope and stream reaches will be defined for aquatic habitat assessment and classification of tributaries in order to characterize ecological structure and function of creeks and tributaries. An initial field reconnaissance will be conducted to identify barriers to migration and identify habitat characteristics. The data review and reconnaissance information will be used to classify tributaries based on aquatic habitat characteristics, and reaches to be sampled will be selected at tributaries and along the mainstem. A review of the WMI Pilot Watershed Assessment, stream segmentation methodology, and suspected limiting factors will be undertaken and incorporated into the habitat assessment.

Conduct In-stream habitat survey. A plan will be developed for conducting a habitat survey for selected species, with a focus on impacts due to potential excessive sedimentation and identification of stressors. A habitat survey will be conducted and concurrent field sampling to collect stream hydrologic, geologic, and morphologic data. This effort will be coordinated with field work for the rapid sediment budget analysis, and any supplemental data collection required for completing the sediment assessment and USGS Include project.

Data collection and analysis will focus on characterizing channel condition and habitat condition with respect to factors limiting the populations of aquatic species, especially threatened and/or endangered native aquatic species. Specifically this shall include the following data analysis:

- An evaluation of erosion and channel sedimentation processes and the influence on flood conveyance (e.g., bank erosion intensity, channel geometry, baseflow, fine sedimentation in pools, etc.);
- An evaluation of the balance between stream sediment supply and transport capability and the consequential effects on aquatic habitat attributes (e.g., pool depth, permeability of spawning gravel, streambed and bank stability, etc.); and
- A characterization of physical water quality parameters and habitat structure (e.g., streamflow, temperature, turbidity, riparian canopy, species distribution, etc.) with reference to life history needs of threatened or endangered aquatic species.

Conduct in-stream habitat assessment. The assessment will be based on information gathered from existing biological studies and the aquatic survey, and incorporating any available data on the amount of fine sediment in streambed gravel and filling of pools to determine the suitability for steelhead spawning and rearing. The Assessment Team will analyze relevant data including data from the habitat survey, field sampling, and existing conditions analysis (Task 2). The assessment will include a list of stressors to aquatic species and potential factors limiting to populations of special status aquatic species (steelhead, red-legged frog, western pond turtle), and list additional data needs required for a limiting factor evaluation.

The analysis will include a description of other possible causes of impairments and stressors not considered for the sediment assessment, and include a listing of data gaps and recommendations for further study (e.g. availability of summer habitat, loss of riparian cover, low flows, instream temperatures, food availability, predation, etc.).

Develop Work Product. Technical Memorandum – Instream Habitat Assessment and Limiting Factors Analysis.

Funding/Resources. Funding of the Limited In-Stream Habitat Assessment will be through the SCVWD (Clean Safe Creeks), conducted by in-house biological resources and contracted services, and in coordination with the Prop 13 Grant Task 4 (Historical and Existing Conditions Analysis – Biological Resources) and Task 5.3 (Rapid Sediment Budget), and in collaboration with watershed studies undertaken by SCVWD, CRMP, WMI, USGS INCLUDE, San Jose State University and Stanford University investigations, as feasible.

4.4 Task 4 – Conduct Watershed Sediment Assessment and Analysis

A comprehensive, multi-discipline assessment will be conducted on a watershed scale to identify and reduce impacts from sediment. The watershed sediment assessment and analysis can be broken down into the following subtasks:

4.4.1 Conduct Rapid Sediment Budget Analysis

Analyze data and information. Using the available resources from Task 1, analyze available data for water quality, flow, precipitation, sediment, and channel morphology. Collect and interpret aerial photographs for evidence of current and historical erosion and other mass wasting. Conduct initial field reconnaissance to ground truth erosion sources identified from aerial photographs. Analyses of upland hillslope processes and determine focus areas.

Develop Approach. The approach for conducting the rapid sediment budget analysis will be developed based on the analysis of existing information, data gaps and needs, site visit, and identified focus areas. The Assessment Team will draft the framework for the Rapid Sediment Budget Analysis and obtain approval of the approach from Regional Board and stakeholders. The framework includes the development of sampling protocol for required field data.

Monitoring Protocol. Develop Monitoring Protocol for field sampling and analysis, including sampling plan and methodology, analytical requirements, quality assurance/quality control, and safety procedures based on *Rapid Evaluation of Sediment Budgets* (Reid and Dunne, 1996).

Conduct Field Work. Conduct sediment assessment field work at focus areas to measure channel and stream bed morphology, stream flow and velocity, grain size distribution, pebble counts and embeddedness, sediment storage, pool volume and filling, gravel permeability, %fines, channel features, aggradations, incision and bank erosion, and road survey. Analyze field data and perform calculations (in office). Incorporate field data and background data into required elements of sediment budget.

Identify sediment sources and characterize loadings. Define type and location of major natural and management relates sources. Estimate amount of sediment contributed by each type of source. Determine grain size distribution of sediment contributed from each source. Transport calculations and analysis to estimate volume and grain sizes of sediment in storage along streams; and estimate transport rate of sediment through stream channels. Calculate Sediment Budget mass loadings entering system, throughput, and percent contribution of loadings from each source class.

Develop work product. 1) Monitoring Protocols presenting approach for Rapid Sediment Budget Analysis and field sampling plan. 2) Rapid Sediment Budget report summarizing sediment budget results, characterizing sediment sources, and providing a description of various sediment input scenarios. All analyses conducted will be described. The report will include a discussion of results and conclusions regarding the primary sources of sediment. 3) Electronic data files and maps.

Funding/Resources. Funding of the Rapid Sediment Budget Analysis will be through the Prop 13 Grant (Task 5), and conducted primarily by participating contractors.

4.4.2 Develop and perform sediment source analysis

Sediment Source Analysis. Identify key sources of anthropogenic sediment impacts in the watershed. Compile an inventory of all sources of sediment to the creek system (assessments of maps, data, and reports and/or field surveys). Conduct geomorphic assessment to assess sediment sources in upper watersheds above Searsville Lake.

Calculate Sediment Loadings and Land Use Contributions. Conduct assessment of the relative location and magnitude of loads from the various sources, focusing on the transport mechanisms of concern, routing of the sediment, and time scale of loading. The approach will include connecting sediment loadings calculations for the creeks of the Upper and West Watershed with the results of the Stanford University Searsville Impact study, and loadings from tributaries to the lake. The sediment delivery processes will be quantified, and estimates of sediment production and delivery rates for each source will be determined.

Natural and Episodic Sediment Loadings. The Assessment Team will define the "natural" state of creek system in order to comparatively assess the negative impact of sediment within the watershed. The natural state of the creek system will be defined in terms of land use, sediment loads, and assessment of the previously agreed-upon indicators. Results of the USGS and Stanford University sedimentation history investigation will be incorporated and translated into sediment loadings from episodic disturbance.

Anthropogenic Land Use Discharges. The contribution of anthropogenic landuse discharges will be determined. Compare existing conditions of the creek to the natural state, and identify factors causing changes.

Develop Work Product. Work products developed for this task primarily include the sediment source analysis, to be presented in the draft Watershed Sediment Analysis Report, including calculations, methodology, and supporting data.

Funding/Resources. Funding of the Sediment Source Analysis task will be supported by Prop 13 Grant (Task 5 – Watershed Sediment Analysis), and conducted by participating contractors, in a coordinated effort, utilizing technical services of USGS, SCVWD, CRMP, WMI, and Stanford

University. The Assessment Team will provide coordination through in-kind services of stakeholders.

4.4.3 Determine Sediment Transport from Headwaters to the Bay

Watershed Model Development and Coordination. The project will utilize the HEC-RAS and HEC-6 hydraulic and sediment transport models to quantitatively assess impacts on the creek system. This task will involve identifying model inputs and defining model parameters, set-up options, and variables.

The watershed modeling approach will utilize existing modeling efforts of the lower watershed, and incorporate prior measurements and surveys in the San Francisquito Creek watershed by SCVWD, JPA, nhc, Balance Hydrologics, USGS, and Stanford University. The geomorphic assessment of San Francisquito Creek will be used as the basis for modeling development for simulating conditions, for considering ongoing changes in the watershed, and comparisons between tributaries.

Assess Episodic Disturbance. The modeling effort will also evaluate the existing effects of episodic disturbance such as floods, fires, landslides, or earthquakes. The nhc/Balance Hydrologics model analysis developed for the Searsville Impact study will be reviewed to estimate the occurrence and effect of each type of episode on coarse sediment supply, and episodic delivery of sediment from the upper watershed.

Develop Work Products. Work products developed for this task primarily include a watershed model analysis and channel sediment transport estimates, to be presented in the draft Watershed Sediment Analysis report. The report will include methodology for quantifying impacts; a description of hydrologic routing, sediment transport, and hydraulic flow models; and the means of translating model outputs to assess target values. The report will describe the results of the modeling effort, as well as model parameters, assumptions, applications, uncertainty, calibration and sensitivity.

Funding/Resources. Funding of the Sediment Transport task will be supported by Prop 13 Grant (Task 2), and conducted primarily by participating contractors, in a coordinated effort, utilizing technical services of USGS, SCVWD, CRMP, WMI, and Stanford University. The Assessment Team will provide coordination through in-kind services of stakeholders.

4.4.4 Characterize channel and habitat condition relative to sedimentation

Assess Sediment Impacts and Impairment. The assessment team will assess current pollutant levels and levels of impairment, and assess known indicator values and criteria for existing and potential management scenarios. An estimate of total loading capacity will be determined for various land use management scenarios, and documenting the type and spatial extent of impacts.

Analysis of Channel and Habitat Condition. The results of the sediment assessment will be presented in tabular format, outlining a determination of the habitat and channel condition status of each stream segment with respect to each beneficial use, stakeholder interest, level of uncertainty, and a list of data used to arrive at the determination. Based on sediment assessment results, potential management options and future channel change will be suggested.

Conceptual Model Development. A conceptual model graphic will be produced, depicting sediment sources and mass loadings, exchanges, hydrodynamic process, sediment transport and flux, flooding, biota and ecological effects.

Develop Work Products. The work products to be developed from this task include the Watershed Sediment Analysis Report, and conceptual model graphic. The assessment team will coordinate and communicate with other stakeholders, projects, and programs for defining, modeling and evaluating various watershed issues and sediment loading scenarios, and prioritize sources of impacts and solution recommendations. The TAC will be convened to review results presented on the sediment assessment and analysis, and the extent and magnitude of impairment.

Funding/Resources. Funding of this task will be supported in part by Prop 13 Grant (Task 5), and conducted by participating contractors, in a coordinated effort, utilizing technical services of USGS, SCVWD and Stanford University. The Assessment Team will provide coordination through in-kind services of stakeholders.

4.5 Task 5 - Project Implementation, Management and Administration

Project Management. Establish project management plan including project schedule and resource allocation, project milestones and deliverables. Develop Priorities for Implementation. Establish project budget breakdown by task and subtask, track labor and direct costs. Conduct monthly project reviews. Utilize an adaptive management approach. Prepare and distribute minutes of the meetings project status reports. Establish a periodic reporting mechanism to inform decision makers of progress and project status.

Assessment Team. The make-up of the Assessment Team will be determined and assembled, consisting of stakeholders, technical experts, and contractors. A Request for Proposals (RFP) will be developed and distributed to a list of qualified consultants. The role of participating team members and estimated labor hours will be defined.

Property Access. Notify Landowners in writing and gather landowner permission for property access. Prepare letter to landowners stating request and purpose of access, and place public notice in local newspaper. Follow up solicitation with telephone calls.

Project Reporting. Project reporting to include Monitoring protocols (Prop 13 Grant deliverable 5.1), Draft/Final historical and existing conditions watershed sediment characterization (Prop 13 Grant Project deliverable 4.1.e/f and 4.2.i/j) and draft/final sediment analysis report (Prop 13 Grant Project deliverable 5.5 and 5.6). Both reports will present the background, procedures, analytical methodology, results, discussion and conclusions undertaken in the development of the conditions characterization and sediment assessment. Project reporting will also include a draft and final Project Report for the Prop 13 Grant San Francisquito Watershed Analysis and Sediment

Reduction Plan (Prop 13 Grant Project deliverable 8.2 and 8.3). Reporting effort includes the preparation of the draft report, stakeholder review and comment of draft report and providing questions, preparation of a final report that incorporates comments from stakeholders, final stakeholder review of final report, and submittal of final report to Regional Board. The final Historical and Existing Conditions Report will be submitted to the Regional Water Quality Control Board by September 30, 2003. The final sediment analysis report will be submitted to Regional Water Quality Control Board by December 15, 2003. The final project report *San Francisquito Watershed Analysis and Sediment Reduction Plan* will be submitted to the Regional Water Quality Control Board by May 28, 2004. The final *Aquatic Habitat Assessment and Limiting Factors Analysis* report will be submitted to the Regional Water Quality Control Board by June 30, 2004.

Presentations. Develop and conduct presentations to regulatory agencies, decision makers, and local interest groups. Present results to stakeholder groups and decision makers including historical and existing condition analysis, and findings of the watershed sediment assessment. Present project approach to regulatory agencies and decision-makers for approval.

Stakeholder participation and project review. Periodic project status and planning meetings with stakeholders will be conducted, to outline milestones, identify upcoming data and work requirements, and solicit feedback on technical and administrative aspects of project. Stakeholder involvements in assessment process include the sharing and distribution of information, educating the group about problems, and communicate legal requirements and Regional Board intentions. The stakeholder workgroup will also provide a forum for dispute resolution.

Public Education and Outreach. Provide external communication, answer questions, and educate the public on TMDL process, control measures implementation, and restoration activities.

Funding/Grants. The stakeholders will investigate and secure sources of funding to perform the watershed sediment assessment and implement corrective measures. Sources of grant funding will be identified, and inquiries of Federal, State, and local agencies, programs, and organizations. Identify possible collaborative partners. Distribute funds to work plan elements, ensure funding is equitable, and determine in-kind funding. Project management of grants received (Prop 13).

Project Protocols. Establish general procedures for running stakeholder meetings and assessment workshops, and documenting the proceedings. Define procedures for handling differences of opinion among experts.

Technical Advisory and Scientific Review. Establish a Technical Advisory and Scientific Review process. Communicate with Advisory and Review panel, and decision makers, to ensure that science informs decisions and that decisions are periodically evaluated and refined as scientific information is improved. Coordinate with JPA to assemble a team of impartial interdisciplinary scientific and technical advisors. Participate and support JPA technical peer review process or technical advisory committee, review products and deliverables, and provide feedback to the TAC. Design projects with decision-makers and integrate information from natural and social science disciplines as appropriate to address their issue of concern. Interface with USGS science liaison to JPA and other appropriate stakeholder groups, such as the San Francisquito Creek Watershed Council and Steelhead Task Force.

Project Coordination. Ensure project is coordinated with other relevant programs and projects in the Santa Clara Basin and San Francisco Bay Area. Identify and coordinate with ongoing assessment and management activities in riparian corridor. Integrate with SCBWMI at appropriate subgroup levels as identified (Core, WAS, FMS). Regulatory Process - Integrate assessment activities with SM-STOPPP and SCVURPPP permit conditions; conduct joint workshop with STOPPP and SCVURPPP. Assist in Technical Review of other sediment assessments or studies. Research other sediment assessments or studies in SF Bay area.

Funding/Resources. Funding of the Project Management will be supported in part by Prop 13 Grant (Task 1) and stakeholder in-kind services in a cooperative effort. JPA staff are serving as contract administrator for the Prop 13 Grant and will be managing project contractual obligations with the SWRCB.

SECTION 5. PROJECT BUDGET

The estimated project budget is shown in Table 2, delineating project hours by task and allocation of funding resources. The budget estimate is based on an hourly labor rate of $105. The Total Budget estimate does not include costs supported by ongoing projects and activities in the watershed, including USGS Include, SCVWD, Watershed Council, and Stanford University studies. This workplan does not include the scope of the Sediment Reduction Plan to be developed under Prop 13 Grant Project Task 6. This element of the project is addressed in the Erosion Control and Prevention Plan submittal by STOPPP on September 1, 2001 and the Assessment of Management Practices submittal by SCVURPPP on March 1, 2002 (revised October 15, 2002).

Table 2. Project Budget for San Francisquito Creek Watershed Assessment Work Plan

Task		Labor (Hours)	Cost ($)				Source/In-kind				
			Total Budget(2)	Prop 13 Grant	Matching Funds	Prop 13 Grant Task	Co-Permittees	USGS Include	SCVWD	Stanford Univ.	Stake-holders
1.0	Gather Existing Data/Information	171	$18,000	$57,000	$10,000	Task 4	X	X	X	X	X
2.0	Existing Conditions Analysis	467	$49,000			Task 4	X	X	X	X	X
3.0	In-Stream Habitat Assessment	2,380	$250,000	0	(3)				X	X	X
4.0	Sediment Assessment and Analysis	571	$60,000	$45,000	$15,000	Task 5	X	X	X	X	X
5.0	Project Management/Administration	532	$55,950	$36,200	$19,750	Task 1, 2,3 & 8	X		X		X
	Assess Management Practices/Sediment Reduction Plan (1)	779	$81,800	$61,800	$20,000	Task 6 & 7	X		X		X
	TOTAL		$514,750	$200,000	$64,750						

(1) This workplan does not include the scope of the Sediment Reduction Plan to be developed under Prop 13 Grant Project Task 5 and 6. This element of the project is addressed in the Erosion Control and Prevention Plan submittal by STOPPP on September 1, 2001 and the Assessment of Management Practices submittal by SCVURPPP on March 1, 2002 (revised October 15, 2002).

(2) The Total Budget estimate does not include costs supported by ongoing projects and activities in the watershed, including USGS Include, SCVWD, and Stanford University studies.

(3) Aquatic Habitat Assessment and Limiting Factors Analysis not funded by Prop 13 grant, and will be funded by the SCVWD (Clean Safe Creeks).

SECTION 6. PROJECT IMPLEMENTATION SCHEDULE

The estimated project schedule is attached in Exhibit A. Table 3 presents project milestones and anticipated date of completion. The project schedule and level of effort coordinates with the scope and schedule, and subsequent completion of the Prop 13 Grant Project as developed by the TAC. The schedule assumes a project start date of October 2002, with project completion and final report submittal to the Regional Board by June 30, 2004.

Table 3. Sediment Assessment Project Milestones

Activity	Time of Effort	Anticipated Completion Date
Establish Prop 13 TAC and Project Assessment Team	Year 1	June 2004
Draft Prop 13 Grant Project scope	Year 1	Dec 2002
Existing Data Summary and Data Gaps	Year 1	June 2003
Historic Conditions	Year 1	June 2003
Existing Conditions Analysis and Reference Conditions	Year 1	Sept 2003
In-Stream Habitat Assessment	Year 2	June 2004
Protocol of Field Measurements	Year 1	June 2003
Rapid Sediment Budget Analysis	Year 1	Oct 2003
Sediment Source Analysis	Year 1	Oct 2003
Characterization of Channel Conditions	Year 1	Nov 2003
Watershed Sediment Analysis Report	Year 2	Dec 2003
Close Project	Year 2	June 2004

APPENDIX A

Prop 13 Grant Project - Watershed Analysis and Sediment Reduction Plan
Contract Exhibit A -Scope of Work